PB-224 580

RECOMMENDED METHODS OF REDUCTION, NEUTRALIZATION, RECOVERY, OR DISPOSAL OF HAZARDOUS WASTE

VOLUME I. SUMMARY REPORT

TRW SYSTEMS GROUP

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY

AUGUST 1973

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

BIBLIOGRAPHIC DATA SHEET

1. Report No. EPA-670/2-73-053-a

2.

PB 224 580

4. Title and Subtitle
Recommended Methods of Reduction, Neutralization, Recovery, or Disposal of Hazardous Waste.
Volume I, Summary Report

5. Report Date issuing date - Aug. 1973

6.

7. Author(s) R. S. Ottinger, J. L. Blumenthal, D. F. Dal Porto, G. I. Gruber, M. J. Santy, and C. C. Shih

8. Performing Organization Rept. No. 21485-6013-RU-00 -Vol-1

9. Performing Organization Name and Address
TRW Systems Group, One Space Park
Redondo Beach, California 90278

10. Project/Task/Work Unit No.

11. Contract/Grant No.
68-03-0089

12. Sponsoring Organization Name and Address
National Environmental Research Center
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

13. Type of Report & Period Covered
Final

14.

15. Supplementary Notes
Volume I of 16 volumes.

16. Abstracts

A summary of the work performed on the hazardous waste research project is presented in the first volume of the 16 volume report. The report includes an updated listing of hazardous waste stream constituents, an evaluation of the adequacy of current waste management practices for these materials, and an identification of the research and development required to provide necessary information or develop adequate treatment methods. The results of this study clearly indicate the requirement for a system of National Disposal Sites to provide a repository for certain classes of hazardous waste stream constituent residues which must be stored and monitored permanently to avoid harm to the public and/or the environment.

17. Key Words and Document Analysis. 17a. Descriptors

Hazardous Waste
National Disposal Site
Waste Management
Treatment Methods

17b. Identifiers/Open-Ended Terms

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
US Department of Commerce
Springfield, VA. 22151

17c. COSATI Field/Group 06F; 06T; 07B; 07C; 07E; 13B; 13H; 19A; 19B

18. Availability Statement
Release to public.

ia

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages 210

22. Price $5.50

EPA-670/2-73-053-a
August 1973

RECOMMENDED METHODS OF REDUCTION, NEUTRALIZATION, RECOVERY OR DISPOSAL OF HAZARDOUS WASTE

Volume I. Summary Report

By

R. S. Ottinger, J. L. Blumenthal, D. F. Dal Porto,
G. I. Gruber, M. J. Santy, and C. C. Shih
TRW Systems Group
One Space Park
Redondo Beach, California 90278

Contract No. 68-03-0089
Program Element No. 1D2311

Project Officers

Norbert B. Schomaker
Henry Johnson
Solid and Hazardous Waste Research Laboratory
National Environmental Research Center
Cincinnati, Ohio 45268

Prepared for
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

ib

REVIEW NOTICE

The Solid Waste Research Laboratory of the National Environmental Research Center - Cincinnati, U.S. Environmental Protection Agency has reviewed this report and approved its publication. Approval does not signify that the contents necessarily reflect the views and policies of this Laboratory or of the U.S. Environmental Protection Agency, nor does mention of trade names of commercial products constitute endorsement or recommendation for use.

The text of this report is reproduced by the National Environmental Research Center - Cincinnati in the form received from the Grantee; new preliminary pages and new page numbers have been supplied.

FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in:

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

Under Section 212 of Public Law 91-512, the Resource Recovery Act of 1970, the U.S. Environmental Protection Agency is charged with preparing a comprehensive report and plan for the creation of a system of National Disposal Sites for the storage and disposal of hazardous wastes. The overall program is being directed jointly by the Solid and Hazardous Waste Research Laboratory, Office of Research and Development, National Environmental Research Center, Cincinnati, and the Office of Solid Waste Management Programs, Office of Hazardous Materials Control. Section 212 mandates, in part, that recommended methods of reduction, neutralization, recovery, or disposal of the materials be determined. This determination effort has been completed and prepared into this 16-volume study. The 16 volumes consist of profile reports summarizing the definition of adequate waste management and evaluation of waste management practices for over 500 hazardous materials. In addition to summarizing the definition and evaluation efforts, these reports also serve to designate a material as a candidate for a National Disposal Site, if the material meets criteria based on quantity, degree of hazard, and difficulty of disposal. Those materials which are hazardous but not designated as candidates for National Disposal Sites, are then designated as candidates for the industrial or municipal disposal sites.

A. W. Breidenbach, Ph.D., Director
National Environmental Research Center
Cincinnati, Ohio

CONTRIBUTORS

Project Management

Robert S. Ottinger
Jack L. Blumenthal

Organic Waste Team

Myrrl J. Santy
Howard Green
J. Warren Hamersma
William Kendrick

Pesticide and Inorganic Waste Team

Christopher Shih
Maksymilian Burk
John Clausen
Dennis Dal Porto
Shou Kwong
Hyman Lubowitz
William Niro

Explosive and Military Waste Team

Gerald Gruber
Charles Bacon
Jack Denson
Charles Murray

Radioactive Waste Team

J. Michael Bell
Kenneth L. Green
Al Aikens, PRS Systems

Metal and Mining Waste Team

Alfred Lee
Marvin Appel

Industrial Waste Analysis

Marvin Rosenfeld
Harry Alsentzer
John Thornton
Peter Williamson
Rollins Environmental Services

Toxicologic Analysis Team

Henry Rutter, Jr.
Anita Curry
Joseph Hiddeman
Hazelton Laboratories

Information System Staff

James Riley
Fumi Oiye

Editorial and Secretarial Staff

Marilyn Jennings
Lynda Broberg
Linda Drake
Linda Drexler
Joan Long
Margarita Ramirez
Vicki Stewart
Barbara Wagar
Barbara Wellwood
Christiane Yarden

ACKNOWLEDGMENT

This program owes much to the program monitors and other staff of the Environmental Protection Agency who provided both advice and insight toward shaping this final report. Special thanks go to the program monitor, Mr. Henry Johnson, his predecessor, Dr. Lynn Wallace, and the staff of the Solid Waste Research Laboratory, National Environmental Research Center, Cincinnati, who have reviewed progress and provided information throughout the program. Thanks are also due to the staff of the Resource Recovery Division, Office of Solid Waste Management Programs, Washington, D.C., particularly Messrs. Sam Morekas, Don Marlow, Al Hayes, and Tom Gross, who also reviewed program progress, made constructive suggestions, and coordinated this project with the related projects sponsored by their organization.

This project relied very heavily on information obtained by personal communication and, therefore, much thanks is due to the individuals providing information. The industrial contacts are too numerous to mention specifically; however, certain individuals within the government sector were especially important in obtaining military and radioactive waste data. The collection of military hazardous waste data was coordinated through Col. Herbert Bell, Office of the Deputy Assistant Secretary of Defense for Environmental Quality, and Col. Walsh, Major Donald Rogers, and other members of the Department of Defense Environmental Pollution Control Committee. Information on radioactive wastes was obtained through Mr. Alex F. Perge, Assistant Director for Operations, Division of Waste Management and Transportation, Atomic Energy Commission, Washington, D. C., Mr. Lou Meyers, Office of Radiation Programs, Environmental Protection Agency, Rockville, and Mr. Charles Hardin of the Kentucky State Department of Health.

The important efforts of our major subcontractors, Hazelton Laboratories and Rollins Environmental Services, deserve appreciation as much information necessary to the successful completion of the project was obtained from

their programs. Finally, the contributions of our editor, Mrs. Marilyn Jennings, and of our secretarial staff have been extremely important to the preparation of our voluminous monthly reports and this final report. We appreciate their efforts.

TABLE OF CONTENTS

VOLUME I

SUMMARY REPORT

Page

1. Executive Summary 1
2. Introduction 7
3. Development of the Information Base 13
4. Analysis of Waste Management Practice 23
5. Determination of Forms and Quantities of Hazardous Wastes . . . 67
6. Research and Development Recommendations and Planning 89
7. Conclusions and Recommendations 113
8. References 118

Appendix: Waste Stream Constituent Analysis Summary 119

1. EXECUTIVE SUMMARY

The report contained in these volumes provides the results of the effort performed by TRW under Contract 68-03-0089 to the Solid Waste Research Laboratory. The program compiled an updated listing of hazardous waste stream constituents, evaluated the adequacy of current waste management practices for these materials, and identified the research and development required to provide necessary information or develop adequate treatment methods.

Under Section 212 of Public Law 91-512, the Resource Recovery Act of 1970, a comprehensive report and plan for the creation of a system of National Disposal Sites for the storage and disposal of hazardous wastes is to be prepared by the Environmental Protection Agency; specifically, the Office of Solid Waste Management Programs and the Solid Waste Research Laboratory. The report is to include a list of materials subject to disposal in a National Disposal Site, current methods of disposal for the listed materials, recommended methods of reduction, neutralization, recovery, or disposal of the materials, an inventory of possible sites, estimated costs of developing and maintaining National Disposal Sites, and other information deemed appropriate. In order to help meet the requirements for this report, the Environmental Protection Agency has issued a series of contracts to develop the data base and provide the necessary analysis.

Listing of Hazardous Materials

The first contract effort, performed by Booz-Allen Applied Research, resulted in a list of over 500 hazardous materials known to be components of industrial waste streams. The final report resulting from that study also summarized waste disposal practices in industries handling the designated materials. The report further indicated that much of the information on the forms in which the hazardous materials are found in the waste streams, the quantities of the wastes, and their distribution within the United States was not present in the literature nor was it available from central sources such as trade associations.

Analysis and Evaluation of Waste Management Practices

The second contract effort was initiated by TRW Systems in December of 1971 with the objectives of (1) defining adequate waste management; (2) evaluating current waste management practices and (3) planning necessary research and development. The starting point for the program was the first contractor's list of over 500 potentially hazardous waste stream constituents. In meeting the first two objectives, the TRW study focused on those waste stream constituents which were initially considered to be probable candidates for National Disposal Sites, these being selected from the first contractor's list and other sources on the basis of extreme toxicity and/or persistence in the environment or very high flammability and/or explosive sensitivity. The necessity of concentrating effort on those constituents expected to be candidates for National Disposal Sites required a working definition of such a disposal facility. Accordingly, the following definition was constructed.

> National Disposal Site: A facility open to public use which must have disposal processing capabilities to properly treat and/or permanently store a designated class of wastes. Such facilities would be limited in number and would be responsible to federal, state, and local jurisdiction to ensure proper handling and disposal of the wastes and that no harm to the public and/or environment can occur.

In order to define criteria for adequate waste management, the hazards associated with the finally selected list of 516 constituents and their disposal were evaluated in terms of toxicity, both acute and chronic, as well as flammability and explosiveness. For example, each of the volatile compounds considered in the study has had provisional limits for concentration in air and the concentration in water determined for 24-hour exposure (see Volume II). The criteria resulting from the hazards analysis were used by TRW to evaluate currently utilized waste management practices for the constituents. The waste management evaluation focused initially on waste streams containing high concentrations of the materials, such as packaged or contaminated wastes. This provided a baseline for the subsequent evaluation of waste management practices for dilute, mixed industrial waste streams and reflected the initial lack of information on dilute or mixed industrial waste streams.

The TRW effort was expanded (in June) to include the determination of waste forms together with their quantities and distribution and the evaluation of waste management procedures as applied or applicable to these streams. This additional effort was limited to those constituents considered to be candidates for National Disposal Sites. Since the necessary information was not available in the literature, the effort utilized industry contacts, consultants, waste disposal firms, and estimates based on the manufacturing processes producing or using the materials. The information obtained under this additional task was used to complete the evaluation of waste management practices applicable to these materials.

In the course of the study, Profile Reports for over 516 compounds were prepared, reviewed, and supplemented for final presentation in this report (see Volumes V through XIII). The Profile Reports summarize the definition of adequate waste management and the evaluation of current waste management practices for their subject waste stream constituents. In addition to providing this information, the Profile Report also serves to designate a material as a candidate for processing and/or storage at a National Disposal Site if the constituent meets criteria based on quantity, degree of hazard, and difficulty of disposal. The designation of candidacy indicates that a Site should have disposal processing technology specifically designed and operated to dispose of the candidate in an adequate way. Hazardous waste stream constituents which were not designated as National Disposal Site candidates were judged to be recyclable or safely disposable using common industrial technology.

Several disposal and waste treatment processes and methods were examined in detail in this program resulting in the preparation of corresponding Process Descriptions. The technology so treated included the ultimate disposal methods, landfills, land burial, ocean disposal, and deepwell disposal; incineration and pyrolysis technology; biological waste treatment technology including activated sludge as well as lagoons; and miscellaneous processing such as ion exchange and solidification. The process descriptions provide general information, design criteria, general economics, and an assessment of the classes of waste to which the processes can be applied. Also indicated is the possible utility of the process at a National Disposal Site.

Research and Development Requirements

The third objective of the TRW program was to develop research and development plans required to initiate programs necessary to provide adequate waste management practices for materials hazardous to man and/or the environment. Two general classes of research and development efforts will be required to assist the EPA activities: (1) efforts to provide data and information where gaps in the information base have been identified and (2) process developments where adequate waste management processes are not available or not sufficiently characterized for general application. A number of information gaps were identified which must be filled if an assessment of effects on man and the environment is to be made. For example, information describing the effects of almost all hazardous materials in the ocean environment are unknown, this despite the fact that the ocean has served as an ultimate disposal site for many of these materials. Information required includes effects of the materials on animal and plant life in the ocean as well as effects of the ocean environment on the materials. Other identified information gaps include: (1) temperature-residence time relationships for pesticides incineration; (2) environmental effects (on plants, soil organisms, etc.) for most materials; (3) qualitative and quantitative characterization of soils as to their ability to stabilize and contain various wastes; and (4) the impact of new air and water pollution controls on the solid waste management problem.

The development of processes and/or procedures which can serve as the basis of adequate waste management practice required both: (1) the identification of materials for which adequate methodology does not exist or is economically untenable and (2) the invention or innovation of adequate processes or procedures. Areas of need identified included decontamination of soil containing arsenic, economic removal of mercury and other hazardous heavy metals from low concentration aqueous waste streams, and chemical stabilization of wastes, i.e., reacting wastes to a form which is environmentally stable. TRW performed proof-of-principle (P.O.P.) experimentation on processes designed to satisfy the needs described above. The identified requirements of both classes and the P.O.P. test results were input to the research and development planning. The outputs of this portion of the effort are the technical plans for projects designed to satisfy the informational needs which were identified in the definition of adequate waste management and the process needs which were uncovered in evaluating current waste management efforts. These technical plans consist of a statement of objectives describing the need, task statements defining the approach and estimates of manpower, schedule, and dollar requirements (see summary in this volume and detail of some efforts in Volume XV).

Conclusions and Recommendations

The results of this study clearly indicate the requirement for a system of National Disposal Sites to provide a repository for certain classes of hazardous waste stream constituent residues which must be stored and monitored permanently to avoid harm to the public and/or the environment. Such sites will also require the processing necessary to reduce wastes to the storable residue form and to package it for storage. Such facilities will require extensive monitoring and reporting to ensure compliance with all regulations and requirements. These facilities will be dependent on government regulations to define their markets. The strong dependence on government suggests a business structure similar to that of a utility particularly if the competition is limited by a lack of suitable sites able to economically service a particular area. If competition is so limited, the rate structure should also be regulated again demonstrating similarity to a utility.

The study has also suggested that a system of controls should be instituted in the disposal of all hazardous waste stream constituents whether they are or are not candidates for National Disposal Site treatment. It was found in many cases that although proper treatment was known within the state of the industrial art, the technology was not uniformly applied to the wastes. The inadequate treatments utilized in certain instances have serious implications to the public or to the environment. Proper controls would include specification of the adequate methods to be used for disposal and monitoring and reporting of disposition of all wastes containing hazardous constituents.

It is also the recommendation of the program that the specific projects outlined in the research and development planning be undertaken as soon as possible to provide information necessary to implementing the National Disposal Site and Hazardous Waste Control measures discussed above. Further, it is recommended that policy research be initiated with the objective of encouraging reuse and recovery of hazardous waste materials. In this latter context, disposal regulation and control should be considered together with current and possible incentives, import or export restriction, and subsidies.

2. INTRODUCTION

The ultimate fate of wastes generated in the normal course of business and other activities has until the recent past received little attention by many industries generating the wastes and by the public at large. To many of the waste generators, the bulk of unusable material was something to be removed from the operating area and gotten out of the way. Often, if there was nothing to be recovered from the wastes, they were buried, lagooned, or stored in battered drums with no determination of the possible hazards. Without the necessary knowledge no attempts were made to segregate hazardous waste materials from the others except on the basis of handling requirements within the facilities. The disposal method to be used usually was decided solely on the basis of economics with the subliminal assumption that the options, used for so many years were adequate. The public, for its part, generally ignored industrial waste disposal practice unless an "accident" occured which focused attention on specific causes and effects. Thus, incidents such as lagoon overflow into a stream with subsequent fish kill, or rupture of a storage drum with subsequent release of odor, would cause public reaction and were generally followed by an action on the part of the waste generator to avoid the same type of incident.

In the late 1960's and in 1970 however, the disposal of hazardous wastes became the object of much public attention. This was true, generally, because of the increased public awareness of the environment and its pollution, and the investigation of the transport and disposal of hazardous wastes generated by agencies of the government. In the specific case of the government waste disposal, congressional investigations focused the attention of both the Congress and the public on the methodology of disposal of hazardous materials. The limited number of options apparently available for disposal, the lack of an information base necessary to determine the best disposal strategy, and the general lack of knowledge relative to all hazardous wastes exposed by those investigations led to the following direction to the Secretary of Health, Education, and Welfare, contained in

Section 212 of the Resource Recovery Act of 1970 (Public Law 91-512).

NATIONAL DISPOSAL SITES STUDY

> "Sec. 212. The Secretary shall submit to the Congress no later than two years after the date of enactment of the Resource Recovery Act of 1970, a comprehensive report and plan for the creation of a system of national disposal sites for storage and disposal of hazardous wastes, including radioactive, toxic chemical, biological, and other wastes which may endanger public health or welfare. Such report shall include: (1) a list of materials which should be subject to disposal in any such site; (2) current methods of disposal of such materials; (3) recommended methods of reduction, neutralization, recovery, or disposal of such materials; (4) an inventory of possible sites including existing land or water disposal sites operated or licensed by federal agencies; (5) an estimate of the cost of developing and maintaining sites including consideration of means for distributing the short- and long-term costs of operating such sites among the users thereof; and (6) such other information as may be appropriate."

This legislation enacted October 26, 1970 was implemented in fiscal 1972 with the award of an initial contract intended to develop the necessary information base for items (1) and (2) of the required report to Congress. The initial contract effort, awarded to Booz-Allen Applied Research, Inc., employed a review of: (1) the chemical process literature; (2) transportation, fire and safety regulations; and (3) information supplied by trade associations, industrial consultants, and government agencies. Utilizing a rating model which considered the quantity of the material produced, the distribution of the material, toxic hazard to man and the environment, and other hazards, such as explosiveness and flammability, a list of materials compiled from the various sources outlined above was narrowed to those materials providing, with respect to this model, the greatest potential harm to man and/or his environment. The industries producing or using these selected materials were identified by the Standard Industrial Code (SIC) and the general waste treatment processes utilized by those industries were determined.

The TRW effort under Contract 68-03-0089 was initiated in December of 1971 with the primary objective of determining the "recommended methods of reduction, neutralization, recovery, or disposal of the listed materials" as specified in the third requirement for the contents of the report to Congress called out in Section 212. The TRW study was divided into seven major tasks directed toward satisfying the primary objective identified above and several secondary objectives: (1) identification of additional materials which would require treatment at a National Disposal Site; (2) identification of current disposal techniques not previously documented; and (3) identification and planning of necessary research. The tasks making up the TRW effort were:

(1) To Define Adequate Waste Management

Toxicity information and standards on each waste stream constituent identified under the first contract or by TRW were reviewed. Other factors, such as flammability and explosive potential, which affect waste management procedures were also considered. Acceptable criteria in terms of impact on mankind and the environment applicable to each of the waste management steps (handling, storage, transportation, disposal, etc.) were defined.

(2) To Evaluate Presently Employed Waste Management Techniques and Policies and Make Recommendations as to Adequacy

The existing techniques for the management of each waste stream constituent were assessed in relation to the criteria defined in Task 1. Preference for one adequate technique over another was stated where possible and the best technique for a National Disposal Site was identified for those materials considered as candidates for such disposal.

(3) To Perform Field Surveys on Existing Waste Management Procedures

In cases where sufficient information to determine the effectiveness of particular waste management techniques was unavailable, site visits were made to facilities utilizing the techniques for discussions with personnel and direct observation of the particular practices.

(4) To Define, Plan, and Outline Research Programs Where Necessary for Elimination of Hazards

Where it was found that information relative to the hazard in employing particular waste management techniques was not well understood or where no adequate techniques were found, remedial efforts were defined, outlined, and planned. The programs were prioritized in terms of importance and probability of success.

(5) To Conduct Proof-of-Principle Experimentation on the Most Promising Concepts

Where a concept could be demonstrated with laboratory experimentation, TRW initiated efforts to provide the proof-of-principle of the concept.

(6) To Determine Waste Forms

Additional information on the hazardous waste stream constituents designated under earlier tasks as candidates for National Disposal Sites were collected, analyzed, and presented as an integral part of this program. The information collected included the forms in which the waste stream constituents are found, their distribution and the quantities of waste materials generated.

(7) To Correlate Total Program Effort

The program was designed and directed to provide this final report which summarizes the best available waste management techniques for each material, lists, on a prioritized basis, those techniques to be included at possible National Disposal Sites, indicates major gaps in current hazardous waste management technology and provides a comprehensive, prioritized research and development plan for obtaining the required technology.

This final report is provided in a multi-volume format reflecting the major technical efforts performed in satisfying the program objectives and tasks as described above. This first volume summarizes the total program effort by providing the program objectives and approach, as well as the results. Volume II contains the toxicologic summary including recommended provisional limits, methods used in determining those provisional limits, and the background data collected for the use of those methods. Volumes III and IV contain detailed descriptions of various waste treatment and disposal processes of common or possible National Disposal Site use.

The major instrument of evaluation and presentation during the study and in this report is the Profile Report. The Profile Report summarizes the information collected on a particular compound or group of compounds and provides the evaluation for that compound. Volumes V through IX contain the Profile Reports on those waste stream constituents determined in the study to be candidates for National Disposal Site processing. These are grouped by application and chemistry. Volumes X through XIII contain the Profile Reports for those waste stream constituents determined in the TRW analysis to be capable of adequate treatment at industrial or municipal disposal sites. The results from the efforts of Task 6, the determination of waste forms and quantities, are provided in Volume XIV. The detailed research and development plans generated under Task 4 in response to deficiencies in the information base and in disposal process technology are provided in Volume XV. Finally, Volume XVI contains the master list of references, ordered by the TRW accession number which is used as the consistent reference number in the process descriptions, Profile Reports, and waste form studies.

The first volume summarizing the program effort is divided into seven chapters, the first two of which are a brief executive summary and this introduction. In Chapter 3 the basic definitions and ground rules are discussed. The analysis of waste management practice is described in Chapter 4 while the waste forms and quantities efforts are summarized in Chapter 5. The rationale developed during the program for the necessary research and development and a summary of research recommendations are provided in Chapter 6. The final section, Chapter 7, contains TRW's conclusions and recommendations regarding various aspects of hazardous waste management as identified in the course of the study.

3. DEVELOPMENT OF THE INFORMATION BASE

The collection, analysis, and evaluation of information which constituted the TRW study required the establishment of a program basis including the ground rules, methodology, and priorities. Specifically requiring definition were the waste stream constituents to be considered, the study priority, methodology of the literature search, and the establishment of an information system.

Development of the Waste Stream Constituent List

When the contract was initiated (December 1971), the Solid Waste Research Laboratory provided TRW with a preliminary list of potentially hazardous waste constituents developed by a previous contractor, Booz-Allen Applied Research, Inc., (BAARINC). This list of waste materials constituted the starting point for the investigation. All analyses of the adequacy of current waste management technology were keyed to the waste stream constituents on the list. Each entry on the supplied list was assigned a unique hazardous material number by TRW which was retained throughout the study. The first level of review was directed toward removing items which were not well enough defined to allow evaluation, such as, mixed acids.

The next level of review required the categorization of the constituents in order to form and assign the research and analysis teams necessary to develop the data base on each material and perform the necessary evaluations. The initial list supplied by the Solid Waste Research Laboratory was divided into five categories: (1) Organic Constituents; (2) Pesticide and Inorganic Constituents; (3) Military and Explosive Wastes; (4) Metals and Mining Wastes; and (5) Radioactive Constituents. This categorization reflects a structure based on both chemical similarity and application similarity. This breakdown correlated the types of compounds, the types of hazards, and the specialties of the staff assigned to the project. Teams of two or more persons were assigned to each category. Their first task was a more detailed review of the assigned waste stream constituents in order to reassess the inclusion of specific materials in the study. At this point in time, February 1972, a revised list contained in the first contractors final report draft was received and the team assignments were again assessed. Materials added to the original Solid Waste Research Laboratory list were added to the TRW list but deletions were generally not applied without further review. Finally each team determined if further additions to the list of waste stream constituents were justified. Biological wastes were excluded from further study. None were in the lists supplied by the Solid Waste Research Laboratory since they are found primarily in municipal waste streams. Two specific areas were found to require further investigation and addition of materials; explosive wastes and radioactive wastes.

Military and Explosive Wastes

While the initial list supplied to TRW contained some explosives such as trinitrotoluene (TNT), no primary explosives or boosters were included as hazardous waste materials. Since these materials are a particularly hazardous handling and transportation problem the Military and Explosive Waste Team undertook a review of the Treasury Department list of explosive materials. The Treasury list was reviewed from the standpoint of selecting materials which would represent the various classes of both primary explosives and secondary explosives which are or could be utilized in military or commercial applications. The factors considered in the selection included explosive sensitivity, the chemical class of the explosive, the metals contained in the explosive, and finally the past, current, and expected future use of the materials. The Department of the Treasury list was narrowed from 217 to 33 including the materials originally included in the lists resulting from the first contract study.

Radioactive Wastes

The initial lists supplied to TRW contained few radioactive waste stream constituents. Therefore, the radioactive waste team initiated a review of the various types of radioactive wastes in order to identify representative waste stream constituents to be included in the analysis. Liquid radioactive wastes are often divided into three categories according to their concentration and hazard potential: high-level; intermediate-level; and low-level. High-level wastes are those with high radioactivity concentration, long half-life and such biological significance that they require perpetual isolation from the biosphere. The sources of all high-level wastes are the reprocessing of spent reactor fuel elements and the weapon production at the AEC facilities.

The term intermediate-level liquid wastes is applicable only to radioactive liquids in processing status. These liquids must eventually be treated to produce low-level liquids which may be released and a high-level concentrate which must be isolated from the biosphere, thus, no intermediate-level wastes, per se, ever require disposal.

Low-level liquid wastes are those wastes which can be discharged into the biosphere without exposing population groups to a radiation level in excess of a small percentage of their normal background exposure to radiation. Wastes generated in the processing phase of the pre-irradiated reactor fuel, along with wastes resulting from research laboratories and medical and industrial applications of radioisotopes are generally considered as low-level.

The term "low hazard potential" is more correct for most solid wastes in that it emphasized radiation safety rather than the concentration of radioactivity.

The large volume, low hazard-potential solid wastes consist typically of paper trash, packing material, broken glassware, protective clothing, and contaminated equipment. Certain other types of solid wastes are small in quantity, but high in radioactivity. Reactor ion-exchange resins, irradiated control rods, metal parts from reactors, and parts of intensely radioactive fuel elements fall into this category.

Materials which are representative of each of the above categories of radioactive waste were selected for further study. The "fission products" selected represent only a small fraction of the total elements produced in a reactor, yet, form 98 to 99 percent of the total watts and curies generated by the reactor fission products after one year. The five actinides selected also account for the majority of activity generated by the reactor actinide products. Finally, several low-level radioactive wastes were selected after reviewing various waste materials on the basis of half-life, production amounts, and type and energy of radioactive emissions.

Establishment of Study Priority

In order to direct the program emphasis toward National Disposal Sites and toward those waste stream constituents to be sent to those sites, the project monitor directed that a preliminary basis for identifying candidate waste stream constituents for disposal at National Disposal Sites be synthesized and applied to the list of waste stream constituents. In concurrence with the direction, a set of preliminary criteria were defined in order to divide the potential candidates for National Disposal Sites from the other materials listed, an exercise needing both a preliminary definition of a National Disposal Site and an assessment of the current data base.

Since Section 212 of Public Law 91-512 provides no definition of a National Disposal Site it was necessary at this point to synthesize for purposes of the study a definition satisfying the requirements for a National Site set forth in the law. The definition finally developed can be summarized as follows:

> National Disposal Site: A facility open to public use which must have disposal processing capabilities to properly treat and/or permanently store a designated class of wastes. Such facilities would be limited in number and would be responsible to federal, state, and local jurisdictions in ensuring the proper handling and disposal of the wastes such that no harm to the public and/or environment can occur.

This definition allows the listing of waste materials and specification of processing required under 91-512, allows for the recognition and inclusion of the burial sites operated in Atomic Energy Commission Agreement States, and at least points the direction for inclusion of private industrial disposal facilities in current operation. In formulating this definition it was not necessary to define the operating mechanisms of a Site other than indicating it must be open to public use and must have adequate treatment processing capabilities for certain designated wastes.

The final designation of these waste stream constituents to be treated at National Disposal Sites required consideration of both the hazards associated with the constituents and the evaluation of the adequacy of the currently practiced treatment and disposal processes. At the initial stage of the program, however, a sufficient information base was developed only for evaluation of the hazard aspects of the waste stream constituents. The initial criteria utilized hazard data, current regulation and judgment to divide the finally selected list of waste stream constituents into three tentative categories: Category 1, candidates for National Disposal Sites; Category 2, candidates for Industrial Disposal; and Cateogry 3, candidates for Municipal Disposal. The criteria developed were as follows:

Category 1: Materials are very difficult to handle, have Thresnold Limit Values less than or equal to 1 ppm, and/or are highly explosive, and/or are very highly flammable, and/or are currently regulated or considered for regulation by the Environmental Protection Agency.

Category 2: Material can be handled by normal industrial procedures, can be incinerated with proper scrubbing equipment, buried without treatment in a Class 1 landfill, or broken down by biological processes as utilized by industry.

Category 3: Materials are relatively easy to handle, can be incinerated without scrubbing, buried in a Class 2 landfill, or treated by municipal sewage treatment processes.

The above criteria were used to divide the updated list of waste stream constituents into the three categories and the following approach was synthesized. Those constituents in Category 1 were to be studied first providing as deep an analysis as possible. Profile Reports (described in Chapter 4) on these materials would be on individual compounds or groups of chemically similar compounds (containing the same metal, for example) and consultants, manufacturers, and users would be contacted to ensure that the currently utilized disposal technology would be identified and included in the analysis. Materials falling into Categories 2 and 3 would be profiled in larger groups collected on the basis of somewhat similar chemistry or similar treatment. The Profile Reports on these materials were to be written in as much detail as possible, following the Category 1 materials.

Literature Search. An extensive survey of the available recent literature related to each waste stream constituent and to the general topic of waste management was conducted to provide much of the information required for the TRW analysis. Abstracts were reviewed by literature research specialists and were flagged when they contained certain predetermined keywords or key phases such as pollution, disposal, sludge, industrial waste, hazardous waste management, municipal waste treatment, etc. Those flagged abstracts were further reviewed by the appropriate research and analysis teams. Documents judged pertinent to the program were ordered and put into the Information System described below. Other forms of technical information such as applicable engineering and scientific reference texts, manufacturers literature describing waste treatment processes and product specification sheets were added to the system when identified and available.

Information Systems. The major elements of the Information Systems and their relationships are best described graphically (Figure 1). The system was structured to process input from the engineering team members in the form of documents, document requests, and lists of literature citations resulting from the literature search. Input from the engineering teams were assigned keywords and/or subject descriptors for inclusion into a keyword index for cross reference purposes. Citations from the literature search were keyworded by the Information System team with additional keywords fed back into the system by the engineering team.

The basic element of the system was the assignment of a unique accession number to each input entry as it began processing. This number was used by the computer for preparation of order forms, keyword index, Theasurus and bibliography. Also, the physical filing of the documents was by accession number, allowing simple retrieval and reasonable assurance that control of file integrity would be maintained.

After assignment of the accession number the document description was entered into the computer data bank. All of the programs used to prepare the various output reports utilized single data bank file, eliminating costly and time-consuming hand data translation.

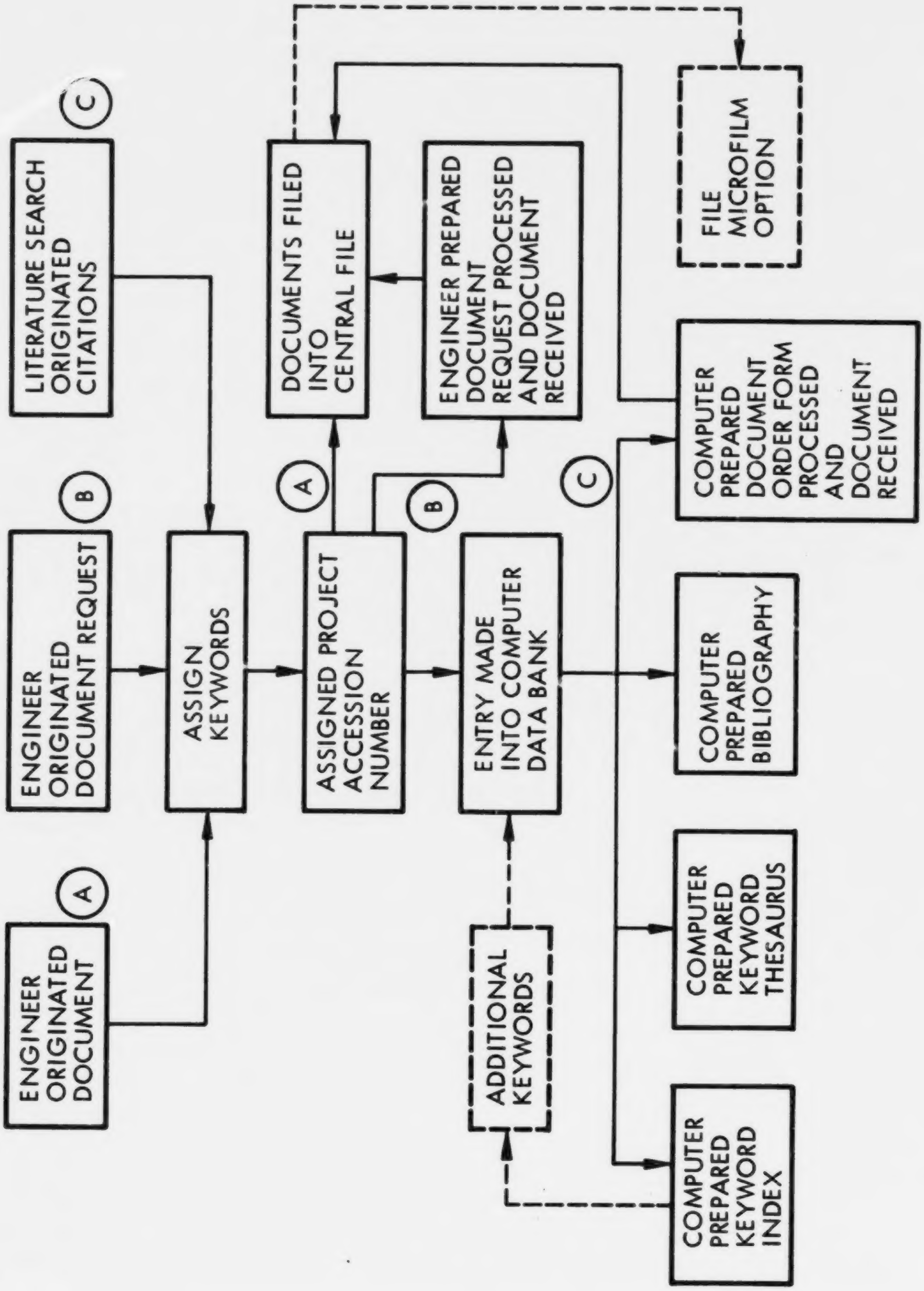

ENGINEER ORIGINATED DOCUMENT
A
ENGINEER ORIGINATED DOCUMENT REQUEST
B
LITERATURE SEARCH ORIGINATED CITATIONS
C
ASSIGN KEYWORDS
ASSIGNED PROJECT ACCESSION NUMBER
A
B
DOCUMENTS FILED INTO CENTRAL FILE
ENGINEER PREPARED DOCUMENT REQUEST PROCESSED AND DOCUMENT RECEIVED
ADDITIONAL KEYWORDS
ENTRY MADE INTO COMPUTER DATA BANK
C
COMPUTER PREPARED KEYWORD INDEX
COMPUTER PREPARED KEYWORD THESAURUS
COMPUTER PREPARED BIBLIOGRAPHY
COMPUTER PREPARED DOCUMENT ORDER FORM PROCESSED AND DOCUMENT RECEIVED
FILE MICROFILM OPTION

Figure 1. Hazardous waste program document control system.

Because of the rapid influx of information during the beginning phases of the program, a regularly scheduled update of the keyword listing and bibliography was established and maintained. Final utilization of the accession number was made by incorporating it as a unique reference number for all reports generated during the Hazardous Waste Program. A bibliography ordered by accession number is presented in Volume XVI.

4. ANALYSIS OF WASTE MANAGEMENT PRACTICE

An assessment was conducted of the adequacy of those waste management practices currently utilized to dispose of hazardous waste stream constituents thought to be possible candidates for national disposal. In order to perform the analysis, the hazards associated with the materials and their disposal (toxicity, flammability, explosiveness, corrosiveness, volatility, radioactivity, etc.), as well as the operational characteristics of the appropriate disposal processes (efficiency, complexity, state-of-the-art, versatility, etc.), were evaluated with respect to a set of established criteria. The results of these evaluations were the determining factors in categorizing the waste stream constituents as being most applicable to national disposal, industrial type disposal, or municipal type disposal.

The vehicles used to document this analysis were the Profile Report and the Process Description. Profile Reports were prepared for each hazardous waste stream constituent or set of constituents having similar physical/chemical properties and requiring similar disposal treatments. Each Profile Report contains a general introduction which characterizes the source of the hazardous waste and details the known physical/chemical properties of the constituent as a pure compound. Additionally, a discussion of the toxicology, radioactivity, and any other hazard associated with the material is presented. Adequate waste management is defined with respect to handling, storage, transportation, and disposal in terms of recommended provisional limits on the concentrations of hazardous materials to which the public can be exposed. Current waste management practices are described and evaluated with regard to their adequacy. The conclusion of the Profile Report is a recommendation as to the most appropriate processing available and the waste treatment category (National Dispoal, Industrial Disposal, or Municipal Type Disposal) in which the individual constituent falls.

Process Descriptions were prepared for selected processes currently utilized for the treatment of disposal of hazardous wastes. These descriptions detail the important features of each process and discuss their applicability to the various classes of waste materials. The preparation of these descriptions also eliminated unnecessary repetition of processing details in each Profile Report.

Preceding page blank

In the following portions of Chapter 4 is a detailed discussion of the individual sections of the Profile Report, including the specific information contained in each section, the relevence of that information to the determination of adequate waste management, and illustrated sections from Profile Reports, and a detailed discussion of Process Descriptions.

The Profile Report is divided into six major sections falling into two categories. The first category involves the characterization of waste stream constituents and includes a general section, a section on toxicology, and a section on other hazards. The second category, characterization of waste management, includes sections on definition of adequate waste management, evaluation of waste management practices, and applicability to National Disposal Sites. These categories and sections are described in detail below.

Characterization of Waste Stream Constituents

Information characterizing each waste stream constituent was collected and is presented in the first three sections of the Profile Reports. This information was utilized in assessing the nature of the particular hazards, the complexity of the waste generation profile (i.e., sources, forms, quantities and geographic distribution), and in determining waste treatment processing applicability. The following is a detailed description of the types of information presented in each of those sections.

General. This introductory section of the Profile Report contains information such as historical background and manufacturing techniques of the constituent as a pure compound or commodity, production rates, use patterns, and types, quantities, sources and distribution of wastes containing the constituent. Furthermore, the pertinent physical/chemical properties of the material are summarized.

The background information serves as an introduction to the Profile Report and generally states the reasons why a particular material appears in the environment as a waste constituent. The manufacturing techniques utilized in the production of the constituent as a commodity (when applicable) were evaluated to determine the forms, sources and distribution of waste associated with production. The production rates and use patterns were utilized in conjunction with waste generation factors for the various applications (generated during the Waste Forms and Quantities Study and discussed in detail in Chapter 5 of this report) to generate a waste production profile in terms of forms, quantities and geographic distribution. This information defined the severity of the waste management problem in terms of quantity and location. Physical/chemical properties of each constituent, as pure compounds, were documented for use in evaluating the applicability of specific treatment processes to the waste constituent. For example, the densities and solubilities of constituents must be known in order to evaluate disposal processes which utilize gravity separation of the constituent from aqueous waste streams. Data on constituent properties such as melting and boiling points, vapor and liquid densities, vapor pressures, flash points, autoignition temperatures, explosive limits, solubilities, acid-base properties, reactivities with specific materials and compatibilities with specific materials were documented on Hazardous Waste Properties Worksheets.

The information presented in the General section of the Profile Reports was obtained from such sources as process engineering texts, technical journals, manufacturers bulletins, Bureau of Census documents, and direct communication with manufacturers, industrial waste treaters and government agencies. The specific sources of information are referenced in the text of the individual Profile Reports and are presented in bibliographies at the end of each report.

The General section for the Profile Report on 2,4-dichlorophenoxyacetic acid (2,4-D) is presented as an example on the following pages.

Example

PROFILE 'ORT

2,4-D (135)

1. GENERAL

Introduction

The discovery of the growth regulating properties of the chlorinated phenoxyacetic acids in 1944 and their subsequent employment as herbicides began the modern era of selective chemical weed control. These compounds are selective to broad-leaved weeds in cereals and could be absorbed from soil as pre-emergent herbicides. The growth regulating action is shared by a group of hundreds of related molecules all derived from the same parent substance, 2,4-dichlorophenoxyacetic acid or 2,4-D. In fact, to permit the proper application and formulation of 2,4-D, the amine salts and esters of the acid have been generally used instead of 2,4-D as such.

The chlorophenoxy groups of herbicides which includes 2,4-D, 2,4,5-T (2,4,5-trichlorophenoxy acetic acid) and MCPA (2-methyl-4-chlorophenoxy acetic acid) comprise approximately half the total domestic herbicide market. The U. S. production figures for 2,4-D from the year 1960 to 1967 in thousands of pounds are:[0449,1610]*

Annual U. S. Production (thousand lb)

1960	1961	1962	1963	1964	1965	1966	1967
361,915	43,392	42,977	46,312	53,714	63,320	68,182	77,139

However, in 1970 only 43,576,000 lb of 2,4-D were produced.[1718] The production figures thus illustrate the gradual declining importance of 2,4-D as a base material for herbicides.

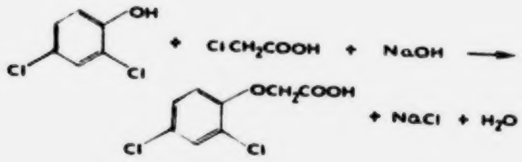
Manufacture

2,4-D is generally prepared by the condensation reaction of monochloroacetic acid and 2,4-dichlorophenol in an alkaline solution at atmospheric pressure, 60 to 80 C, and a residence time of 6 to 8 hr in a jacketed stirred reactor.[1610]

---

*These reference numbers refer to the Profile Report bibliography at the end of the report on 2,4-D.

Example



Large scale commercial facilities for the manufacture of technical grade 2,4-D in the United States include the following[1774, 1775, 1776, 1777, 1778, 1779, 1780]:

Dow Chemical Company, Midland, Michigan
Rhodia Inc., Chipman Division, Portland, Oregon
Transvaal Inc., Jacksonville, Arkansas

The Transvaal plant was formerly operated by Hercules Inc.

Uses

The chlorophenoxy acids are active by contact and by translocation from leaves to roots of perennial weeds and are used as pre-emergent applications to the soil for control of young seedlings. They are also effective for aquatic weed control, for the elimination of unwanted vegetation, and are selective against many broad-leaved annual weeds in cereal and grass crops.[0509]

In addition, 2,4-D and its derivatives have also found important uses in related fields such as thinning of fruit, prevention of preharvest drop, fruit setting, promotion of rooting and postharvest decay prevention.[0509]

Sources and Types of Pesticide Wastes

The sources of pesticide wastes may include the following:[0620] (1) pesticide manufacturers; (2) pesticide formulators, (3) pesticide wholesalers; (4) professional applicators; (5) cooperage facilities that recondition drum; (6) agricultural users; (7) government facilities that store, transport, and use pesticides; (8) urban and suburban home and garden users; (9) commercial and industrial processes including those from rug and fabric treatment facilities manufacturing plants, hospitals, etc.

Example

In general, pesticide wastes can be classified as either diluted or concentrated wastes. Diluted pesticide wastes include those generated in the waste waters of the manufacturers, formulators, agricultural runoffs, and possibly spent caustic solutions used to clean empty pesticide containers. Concentrated pesticide wastes include any unused or contaminated pesticides, pesticide materials left in containers after emptying, sludges formed in treating waste water containing pesticides, sawdust or straw used to soak up accidental pesticide spills.

Unlike most pesticides, 2,4-D is also used as an aquatic herbicide and applied directly to lakes, rivers, irrigation waterways, and other surface waters for weed control, thus posing a potential water pollution problem. 2,4-D has been reported to persist for several months in lake waters.[1757]

Chlorophenoxy pesticides appear as waste stream constituents in varied forms and compositions. Typical waste streams containing chlorophenoxy compounds are as follows:

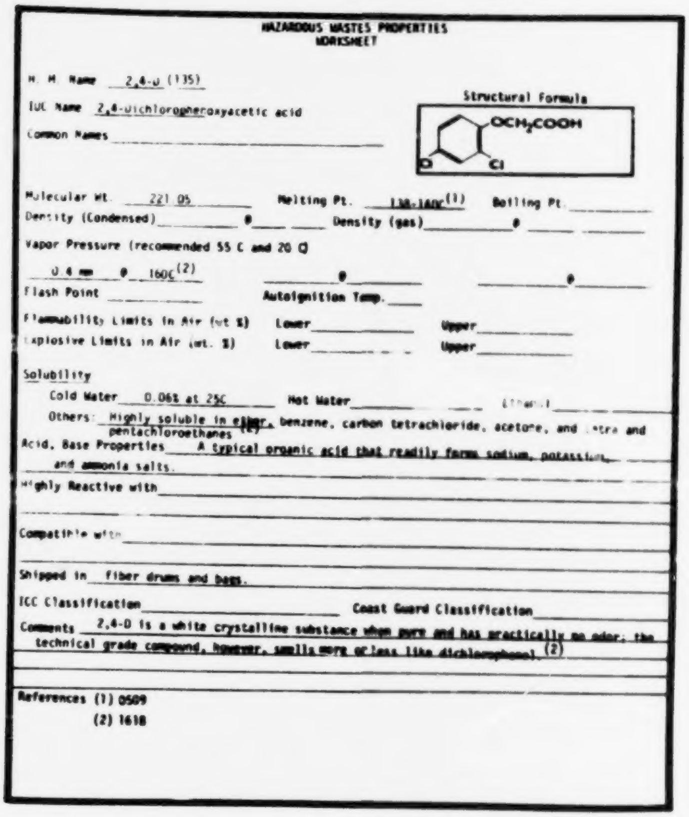
> Solvents including toluene and xylene containing 1 to 5 percent 2,4-D and/or 2,4,5-T
>
> Organic waste containing 20 to 25 percent 2,4-D; 20 to 25 percent 2,6-D; 10 to 15 percent mono- and trichlorophenoxy acetic acids
>
> Still bottoms containing 2,4-D, 2,6-D and chlorophenols.
>
> Solid wastes containing 0.5 percent 2,4-D

More detailed information relating to the forms and quantities of waste chlorophenoxy compounds is presented in the volume titled Waste Forms and Quantities.

Physical and Chemical Properties

The physical and chemical properties of 2,4-D are summarized in the attached worksheet.

Example



HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. W. Name 2,4-D (135)

IUC Name 2,4-Dichlorophenoxyacetic acid

Common Names

Structural Formula

OCH₂COOH
Cl
Cl

Molecular Wt. 221.05 Melting Pt. 138-140C(1) Boiling Pt.

Density (Condensed) @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

0.4 mm @ 160C(2) @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 0.06% at 25C Hot Water Ethanol

Others: Highly soluble in ether, benzene, carbon tetrachloride, acetone, and tetra and pentachloroethanes (2)

Acid, Base Properties A typical organic acid that readily forms sodium, potassium, and ammonia salts.

Highly Reactive with

Compatible with

Shipped in fiber drums and bags.

ICC Classification Coast Guard Classification

Comments 2,4-D is a white crystalline substance when pure and has practically no odor; the technical grade compound, however, smells more or less like dichlorophenol.(2)

References (1) 0509

(2) 1618

Toxicology or Radiation Hazard. For Profile Reports discussing non-radioactive substances, this section has the title Toxicology. For reports dealing with radioactive materials, this section was titled Radiation Hazard even though in some cases toxicological information about the radioactive material was also presented.

The information presented in these sections of the Profile Report was utilized to assess the toxicological and radiation effects exhibited by man, animals, and plant life following exposure to the waste stream constituents of concern. Primary emphasis was placed on toxicological and radiation effects in man.

The toxicological information generally documented included recommended Threshold Limit Values (TLV) for man, Maximum Allowable Concentrations (MAC) for man, Median Tolerance Limits (TL_m) for fish, acute oral and dermal (LD_{50}) values for various forms of animal life, plant reactions following exposure, and exposure symptoms in man. The TLV, MAC, TL_m and LD_{50} may be defined as follows:

TLV - The concentration of an airborne constituent to which workers may be exposed repeatedly, day after day without adverse effect.

MAC - The concentration of a pollutant considered harmless to healthy adults during their working hours, assuming that they breathe uncontaminated air for the remainder of the time (the MAC is generally being replaced by the TLV).

TL_m - The concentration of a pollutant that kills 50 percent of the test organisms (usually aquatic life) within a specified time span, usually 96 hours or less.

LD_{50} - The quantity of a pollutant that kills 50 percent of the test species (usually white rats) after a given exposure or dosage within a specified time span, usually 48 hours or less.

This information was the primary basis from which Recommended Provisional Limits (discussed in detail later in this chapter in the section describing the portion of the Profile Reports titled Definition of Adequate Waste Management) for waste stream constituents were derived.

Toxicity data were obtained from open literature. The bulk of the information was obtained from publications of the American Conference of Governmental Industrial Hygienists, the American Industrial Hygiene Association, the National Institute for Occupational Safety and Health, and the Battelle Memorial Institute publication, "Control of Spillage of Hazardous Polluting Substances". The specific data obtained from these and other sources are individually referenced in each Profile Report and the appropriate references are cited in the bibliographies of each report. All of the data utilized during the course of the Hazardous Waste Disposal Study is documented in Volume II, "Toxicologic Summary".

Information presented in the Radiation Hazard section of the Profile Reports generally discusses such topics as radioactive half-lives, exposure effects in man, recommended standards for long exposure, as well as permissible total body and organ burdens. Information sources were for the most part government agency (mainly Atomic Energy Commission) documents and were individually referenced in each Profile Report.

The radiation hazard information generally documented is expressed in terms of rads, rems, and curies, defined as follows:

Rad - Radiation Absorbed Dose - the absorbed dose of any nuclear radiation which is accompanied by the liberation of 100 ergs of energy per gram of absorbing material.

Rem - Roentgen Equivalent Man - a criterion of biological injury which is defined as:

Dose in rems = dose in rads x (Relative Biological Effectiveness)
= dose in rads x

$$\frac{\text{physical dose of 200 -ky X-rays to produce effect of interest}}{\text{physical dose of comparison radiation to produce same effect}}$$

Curie - a unit of radioactivity equal to 3.7 x 10^{10} disintegrations per second.

The following examples are typical Toxicology and Radioactive Hazard sections taken from the Profile Report discussing 2,4-dichlorophenoxyacetic acid (2,4-D) and the report covering carbon-14, cobalt-60, iridium-192 and radium-226.

Example

2. TOXICOLOGY

2,4-D is of moderate acute toxicity to mammals. The acute oral and dermal LD_{50} values to the rat have been reported to be 375 and 1500 mg/kg body weight respectively.[1277] Inhalation of 2,4-D dusts and sprays is relatively harmless, and percutaneous absorption is negligible.[0449]

Chronically 2,4-D is of low toxicity, and can be ingested by animals and man in daily dosages approaching those which produce acute toxic effects when given only once. Thus, the cumulative effects of 2,4-D are minimal.

The American Conference of Governmental Industrial Hygienists 1971 recommended Threshold Limit Value (TLV) for 2,4-D in air is 10 mg/M^3.[0225]

The 48-hour Median Tolerance Limit (TL_m) for 2,4-D established by the Federal Water Pollution Control Administration for various types of fresh water organisms in micrograms per liter are:[0536] P. Californica (stream invertebrate), 1,800; Daphnia pulex (cladocerans), 3,200; Rainbow trout (fish), 960; and Gammarus lacustris, 1,800. These data are indicative of the hazards to aquatic life associated with the use of 2,4-D.

Example

2. RADIATION HAZARD

Radium-226 is one of the most hazardous radioactive materials known. Radium-226 replaces calcium in the bone structure and is a source of irradiation to the blood-forming organs. This, along with its long half-life (1,602 years) and high radiation energies, places it in the highest radiotoxicity group. It also has the longest history of use of any radioactive material, and most of the standards for the effects of ionizing radiation on man are based on this material. Carbon-14, cobalt-60 and iridium-192 are moderately dangerous radioactive materials.

The effects of their radiation exposure are primarily dependent on the amount of radiation and the portion of the body affected. The effects of whole-body gamma radiation exposure are: (1) 5 to 25 rads, minimal dose detectable by chromosome analysis or other specialized analyses, but not by hemogram; (2) 50 to 75 rads, minimal acute dose readily detectable in a specific individual (e.g., one who presents himself as a possible exposure case); (3) 75 to 125 rads, minimal acute dose likely to produce vomiting in about 10 percent of people so exposed; (4) 150 to 200 rads, acute dose likely to produce transient disability and clear hematological changes in a majority of people so exposed; (5) 300 rads, median lethal dose for single short exposure.[2666] These effects are for a single large dose of radiation or a series of substantial doses in a short interval of time to the total body. The dose delivered to a particular body organ following the inhalation of 1 microcurie of each of these radionuclides is attached (Table 3). For radium-226 the dose delivered to the bone is 300 rem following the inhalation of 1 microcurie (1.01 micrograms). The dose delivered to the bone following the injection of 1 microcurie into the body via a wound is 1,000 rem.

Standards for prolonged exposure over a fifty year period have defined the single dose limit in terms of the maximum permissible dose accumulated in a period of 13 weeks. The whole body exposure limit is 3 rem per quarter for a radiation worker and the accumulated dose limit is 5(N - 18), where N is the individual's age in years. Limits for the thyroid, bone, and other organs have also been defined. Values of the total body burden for each radionuclide required to produce the maximum permissible dose rates defined above have been compiled.[0563] For radium-226 and carbon-14 the critical organ is the bone and the maximum permissible body burden is 0.1 and 300 microcuries, respectively. For cobalt-60 the critical organ is the total body and the maximum body burden is 10 microcuries. For iridium-192 the critical organ is the kidney and the maximum body burden is 6 microcuries.

Other Hazards. This section of the Profile Reports documents any hazards, other than toxicological or radiation hazards, associated with the subject waste stream constituent. The types of hazards reported in this section include the following:

Flammability -	discussion of fire hazards when the material is exposed to heat, flame, and/or oxidizing agents.
Explosiveness -	discussion of the conditions under which explosion will occur. Lower and upper explosive limits are given where applicable.
Corrosiveness -	material incompatibilities with the waste constituent are discussed where applicable.
Detectability -	problems in detectability such as low odor levels and lack or delay of exposure symptoms are discussed where applicable.

The information sources are referenced in the bibliographies of each Profile Report. An example of the Other Hazards section, extracted from the Profile Report on mercury and inorganic mercury compounds, is presented.

Example

3. OTHER HAZARDS

All inorganic mercury compounds, with the notable exception of the halides, decompose to give toxic fumes of mercury on heating.

In addition to its toxic properties, mercuric nitrate also possesses some of the properties of nitrates. Acetylene forms a sensitive acetylide when passed into an aqueous solution of mercuric nitrate. Alcohols should not be mixed with mercuric nitrate, as explosive mercury fulminate may be formed. Reactions of mercuric nitrate and phosphine give a yellow precipitate, which explodes when heated or subjected to shock. Mercuric nitrate also reacts with unsaturates and aromatics with violence if given time to generate enough heat, and could lead to explosions in its use for determining sulfur in Ball's reaction.[0096 *]

---

*Refers to bibliography in the Profile Report on mercury.

Characterization of Waste Management

The final three sections of the Profile Reports, Definition of Adequate Waste Management, Evaluation of Waste Management Practices, and Applicability to National Disposal Sites, present criteria for adequate waste management, treatment descriptions and judgements of adequacy and recommendations as to the class of treatment required (National Disposal, Industrial Disposal and Municipal Type Disposal) for safe constituent disposal.

Definition of Adequate Waste Management. This section of the Profile Report discusses adequate waste management in terms of current storage, handling and transportation techniques and the rules and regulations regarding those techniques. Additionally, maximum permissible ambient concentrations of the waste stream constituent in air, water and soil, designated as Recommended Provisional Limits, are presented. The possibility of recycling the waste constituents when they appear in appropriate form (usually concentrated and lacking specified impurities) is discussed and the names of manufacturers who expressed a willingness to accept those materials are presented.

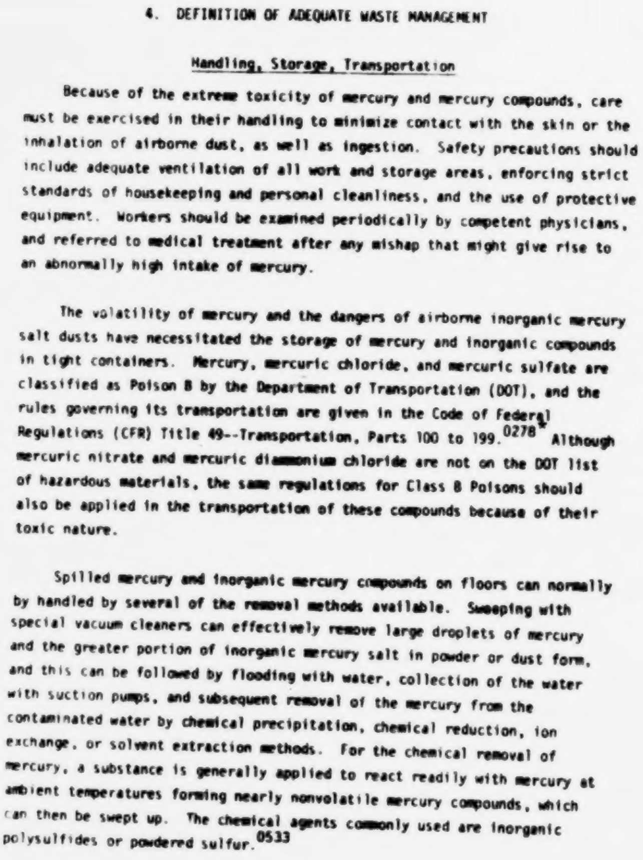
This information was utilized to assess the hazards associated with the handling and transportation of the constituents as well as the dangers associated with the various waste treatment processes discussed in the individual Profile Reports.

Criteria for adequate storage facilities and transportation were determined and are detailed in terms of container material specifications, preferably storage temperature, pressure and specific diluent environments when required, as well as the need for separate storage or requires segregation from other constituents when appropriate. Shipping and storage requirements as specified by regulating government agencies and associations such as the Department of Transportation, the International Air Transport Association and the U. S. Coast Guard are summarized and/or referenced. Handling precautions are described in terms of protective clothing requirements and special handling equipment requirements. This information was utilized to assess the overall hazard associated with the waste management sequence between waste constituent generation and waste disposal.

Adequate waste management is defined in terms of maximum acceptable levels of occurrence in air, water and soil, based mainly but not solely on the toxicological effects of the waste constituent. Those maximum acceptable levels of occurrence were designated Recommended Provisional Limits and are tabulated in this section of the Profile Reports. The Recommended Provisional Limits in air represent the maximum constituent concentration considered safe in terms of continuous exposure in the air outside the physical boundaries of any processing facilities. This limit is equal in value to one-hundredth of the established Threshold Limit Value. For constituents for which no Threshold Limit Value has been established, that of a structurally related compound was used. The Recommended Provisional Limits in water and soil represent the maximum constituent concentrations considered safe in terms of continuous exposure in potable water sources and soil outside the boundries of processing facilities. The Recommended Provisional Limits in water and soil are equal in value, based on the worst case assumption that contaminated soil is completely non-retentive and that the contaminant eventually percolates to the ground water table and eventually becomes potable water. These concentration limits are equal in numerical value to either established current drinking water standards or one-hundredth of the reported lowest drinking water study level in cases where no drinking water standards currently exist. When no standards existed and no study limit values could be found, the value was calculated on the basis of one-hundredth of the limit as calculated by the Stokinger and Woodward Method (based on TLV's). When the calculation method had to be applied, and no established Threshold Limit Values existed, the Threshold Limit Values for structurally similar compounds were used. A detailed description of the methods utilized as well as tabulated values for Recommended Provisional Limits for every waste constituent is presented in Volume II, "Toxicologic Summary". Also contained in the summary tables in Volume II are Recommended Provisional Limits in water for fish, Threshold Limit Values, Maximum Allowable Concentrations, toxic concentrations for selected animal species, percent theoretical Biological Oxygen Demands, critical fish toxicities, and Median Tolerance Limits for fish for each waste stream constituent evaluated.

The following is an example of the Definition of Adequate Waste Management section taken from the report discussing mercury and inorganic mercury compounds.

Example



4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage, Transportation

Because of the extreme toxicity of mercury and mercury compounds, care must be exercised in their handling to minimize contact with the skin or the inhalation of airborne dust, as well as ingestion. Safety precautions should include adequate ventilation of all work and storage areas, enforcing strict standards of housekeeping and personal cleanliness, and the use of protective equipment. Workers should be examined periodically by competent physicians, and referred to medical treatment after any mishap that might give rise to an abnormally high intake of mercury.

The volatility of mercury and the dangers of airborne inorganic mercury salt dusts have necessitated the storage of mercury and inorganic compounds in tight containers. Mercury, mercuric chloride, and mercuric sulfate are classified as Poison B by the Department of Transportation (DOT), and the rules governing its transportation are given in the Code of Federal Regulations (CFR) Title 49--Transportation, Parts 100 to 199.[0278]* Although mercuric nitrate and mercuric diammonium chloride are not on the DOT list of hazardous materials, the same regulations for Class B Poisons should also be applied in the transportation of these compounds because of their toxic nature.

Spilled mercury and inorganic mercury compounds on floors can normally by handled by several of the removal methods available. Sweeping with special vacuum cleaners can effectively remove large droplets of mercury and the greater portion of inorganic mercury salt in powder or dust form, and this can be followed by flooding with water, collection of the water with suction pumps, and subsequent removal of the mercury from the contaminated water by chemical precipitation, chemical reduction, ion exchange, or solvent extraction methods. For the chemical removal of mercury, a substance is generally applied to react readily with mercury at ambient temperatures forming nearly nonvolatile mercury compounds, which can then be swept up. The chemical agents commonly used are inorganic polysulfides or powdered sulfur.[0533]

---

*Refers to bibliography in this specific Profile Report.

Example

Methods suggested for treating water spills of mercury and inorganic mercury compounds include adsorption with activated carbon and ion-exchanger masses such as the Q-13 resin. Results of experiments conducted at the Cornell Aeronautical Laboratory (CAL) has shown that an activated carbon dose of 500 ppm could effect greater than 99 percent removal of mercury from water with an initial mercury concentration (as mercuric chloride) of 100 ppm, and it has been suggested the activated carbon could best be introduced into the stream in water-permeable bags which would allow the pollutant-laden water to pass through the bag material and interact with the contained carbon.[1419] Ion-exchanger masses that could be employed in treating water spills of mercury will be discussed later along with other methods for removing mercury and inorganic mercury compounds from liquids.

Disposal/Reuse

The greater portion of mercury and inorganic mercury compounds present in air and water waste streams can be removed and the mercury recovered for its value. However, although zero mercury discharge is the eventual goal of all concerns, this is not achievable with current technology, especially when economical factors are also considered. For these reasons, the safe disposal of mercury and inorganic mercury compounds must still be defined in terms of recommended provisional limits in the atmosphere and potable water source and/or marine habitat. The provisional limits are as follows:

Contaminant in Air	Provisional Limits	Basis for Recommendation
Mercury	0.0005 mg/M^3	0.01 TLV
Mercuric Chloride	0.0005 mg/M^3 as Hg	0.01 TLV
Mercuric Nitrate	0.0005 mg/M^3 as Hg	0.01 TLV
Mercuric Sulfate	0.0005 mg/M^3 as Hg	0.01 TLV
Mercuric Diammonium Chloride	0.0005 mg/M^3 as Hg	0.01 TLV

Contaminant in Water and Soil	Provisional Limits	Basis for Recommendation
Mercury	0.005 ppm (mg/l)	U. S. Drinking Water Standard
Mercuric Chloride	0.005 ppm (mg/l) as Hg	U. S. Drinking Water Standard
Mercuric Nitrate	0.005 ppm (mg/l) as Hg	U. S. Drinking Water Standard
Mercuric Sulfate	0.005 ppm (mg/l) as Hg	U. S. Drinking Water Standard
Mercuric Diammonium Chloride	0.005 ppm (mg/l) as Hg	U. S. Drinking Water Standard

Evaluation of Waste Management Practices. In this section of the Profile Reports, the specific waste treatment techniques currently utilized or applicable to the subject waste stream constituents were evaluated in the context of disposal efficiency, operational safety and environmental impact. Current methods of waste treatment for the various constituents were determined through review of the Booz-Allen study, other technical literature and direct contact with manufacturers and waste disposers. An understanding of each of those methods and their limitations was essential in evaluating the applicability and adequacy of a particular process or combination of processes for the treatment of each hazardous waste constituent. For that reason, preparation of Process Descriptions discussed later in this chapter detailing the important features of the common waste treatment processes became necessary. The preparation of these Process Descriptions also eliminated unnecessary repetition of processing details in each Profile Report.

The general conclusions reached in the Process Descriptions together with information obtained from manufacturers and waste disposers knowledgable in the application of the various processes to the specific waste constituents, were the basis for the adequacy judgements presented in the Evaluation of Waste Management Practices sections of the Profile Reports. The following is an example of the section from the Profile Report discussing barium compounds and is a representative Evaluation of Waste Management Practices section.

Example

5. EVALUATION OF WASTE MANAGEMENT PRACTICES

Dilute Waste

Option No. 1 - Precipitation. By far the most widespread method used for removing barium from industrial waters is precipitation with sulfate ion (usually sulfuric acid) in settling ponds.[1794] The precipitate formed, $BaSO_4$, is only slightly soluble in water and the resulting effluent from the pond contains about 2 ppm of barium. This effluent would then be diluted with an equal amount of water to meet the permissible criteria for barium in public water supplies (1.0 ppm). Precipitation and settling is normally a slow procedure and with high effluent flow it is normally necessary to have settling ponds or lagoons in which to allow the slow coagulation process to occur, the clear effluent removed and the precipitate dried. Since barium sulfate is important in the barium industry (see section on Manufacturing) it can be economically recycled. This method can be used for both concentrated and dilute barium wastes. In the case of barium cyanide wastes, the cyanide must be removed first before precipitating the barium with sulfuric acid. The primary method of removing cyanide is to oxidize it to CO_2 and N_2 with an alkaline chlorine solution. Other methods for removing cyanide include ion exchange, electro-oxidation, and reaction with aldehydes (refer to Profile Report on cyanides for additional information). Barium could also be precipitated by chromate ion to form barium chromate. This is a workable method but is not normally economically feasible unless a market as pigments for the precipitate is available.

Option No. 2 - Ion Exchange. Ion exchange can be used to remove barium from dilute aqueous waste streams. Barium will behave much like calcium and magnesium and can be removed from an aqueous waste stream by either a sulfonic acid type cation exchange resin or a carboxylic weak acid type resin, depending upon the pH of the stream.[1795] An ion exchange unit cannot usually handle an influent concentration load above 1500 ppm. An advantage of ion exchange is that due to the concentrative effects it is possible to apply this process in recycling barium materials or in concentrating wastes for transport to centralized disposal. The major difficulty in ion exchange operation is the critical dependence on flow rate. The ion exchange system is designed to operate with a particular efficiency at a certain set flow. Should this flow be exceeded for even short periods of time, the efficiency for absorbing the barium ion decreases drastically causing the effluent to exceed the permissible limit.

Example

Option No. 3 - Reverse Osmosis. The effectiveness of reverse osmosis to remove barium from water has been investigated by Sourirajan.[1812] Following passage of a barium waste stream through a porous cellulose acetate membrane, it was found that the barium concentration was reduced from 34.35 g/liter to 7.35 g/liter. It is conceivable that "R.O." is applicable to dilute barium salt solutions as well, but no data is available to support this assertion. With an effluent concentration of 7.35 g/liter, the "R.O." unit would have to be used in conjunction with some other process (ion exchange for example) to produce an effluent with a permissible concentration of barium.

Option No. 4 - Adsorption on Activated Carbon. Activated carbon has been shown to remove barium from acetate solutions by Kuzin et al.[1813] Although the laboratory investigation was principally directed towards the separation of uranium from other metallic compounds; it was found in the same study that activated carbon possessed a sorption capacity for soluble barium compounds of 0.7 mg/g carbon, thus demonstrating the feasibility of activated carbon adsorption as a near future process for removing soluble barium compounds from water.

The processes mentioned above deal exclusively with barium wastes in the conventional aqueous form. If, however, the barium wastes are present in the particulate form in a gas stream, the usual methods for removal of particulates, such as bag filters, electrostatic precipitation, and wet scrubbers should prevent their escape to the atmosphere.[0646]

The best method for disposing of both dilute and concentrated aqueous barium wastes is precipitation with sulfate ion. The technique is efficient and adequate for large scale removal of barium.

The other processes discussed (ion exchange, reverse osmosis, and adsorption on activated carbon) will result in reduced amounts of waste barium but are not applicable as primary treatment methods. These processes should function mainly as a secondary treatment of the effluent from a barium precipitative facility.

Applicability to National Disposal Sites. This final section of the Profile Report recommends the general class of waste treatment required by the subject waste stream constituents. The basis of the recommendation is also presented. The constituents were characterized as requiring either National Disposal Site treatment, common industrial type treatment, municipal type treatment or any combination thereof. Constituents requiring industrial type disposal are defined as materials which can be handled in industry with normal precaution but which require special disposal techniques such as combustion with scrubbing or long-term biological oxidation. Constituents requiring municipal type disposal are defined as materials which require some safety precautions and proper choice of municipal type treatment such as combustion with air in a pollution-free manner, common municipal sewage treatment procedures, or common municipal landfill procedures. Characterization as requiring National Disposal Site treatment was based upon a set of criteria generated during the course of the program. The formalized set of criteria (Table 1) reflect: (1) abundance of the material present as wastes; (2) the degree of hazard associated with the waste material; and (3) the complexity of the treatment that is required in the disposal/recovery of the waste material.

It should be emphasized that these criteria are all qualitative in nature, and a value judgement was exercised in Profile Report evaluations when an individual investigator identified a waste stream constituent as a National Disposal Site candidate. It was also not always necessary for a hazardous material to satisfy the quantity requirement in order to qualify as a National Disposal Site candidate, as exemplified by the low volume high-level radioactive wastes.

In addition to the formal criteria that were developed, considerations were also given to other factors in the identification of National Disposal Site candidates. These included the transportability of the waste material, economics of the waste treatment at low volumes, the amount of training required for waste treatment personnel, technical knowledge of the personnel generating the waste material, and the recyclability of the waste material

TABLE 1.

CRITERIA FOR THE IDENTIFICATION OF CANDIDATES FOR NATIONAL DISPOSAL SITES

QUANTITY CRITERION

(1) Material is present in sizable quantities as a waste.

HAZARD CRITERIA

(1) Waste material is highly toxic.

(2) Waste material is toxic and not degraded, oxidized, reduced or combined to a nontoxic form by air, water, or soil organisms.

(3) Waste material is radioactive with long half-life and/or high level radiation.

(4) Waste material is spontaneously combustible or is an explosive sensitive to heat or mild shock.

TREATMENT CRITERIA

(1) No disposal method other than long term or permanent storage is considered adequate for the material.

(2) Adequate disposal techniques for the material are too specialized or complex for general application.

(3) Adequate disposal methods for the material are under development but not yet available, requiring short term storage.

as a valuable resource. For example, transportability criterion meant that gaseous wastes and dilute aqueous wastes would not normally be considered for treatment at National Disposal Sites. The economical and the high training requirements led to the conclusion that hexavalent chromium and cyanide wastes, which are generated by a large number of small plating shops, should be considered as candidates for National Disposal Sites. Pesticides are handled by farmers and household users lacking knowledge of the properties of their compounds and this provided an additional reason that they be considered as candidate waste stream constituents requiring National Disposal Site treatment. Lastly, manufacturers of certain hazardous materials indicated a willingness to accept wastes containing these materials for reprocessing/recovery, thus eliminating the need for National Disposal Site treatment.

This section of the Profile Report also recommends the appropriate disposal techniques and their order of preference when the specific hazardous waste constituent under discussion has been judged a National Disposal Site candidate.

The Applicability to National Disposal Sites sections from Profile Reports dealing with a National Disposal Site candidate (2,4-dichlorophenoxyacetic acid) and noncandidate (carbon disulfide) are illustrated in the following example.

Example

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

It is anticipated that disposal systems to handle both dilute and concentrated 2,4-D will still be required at National Disposal Sites located near formulators, users, and especially agriculture centers in the near future. The dilute 2,4-D wastes that will require treatment include spent cleaning solutions for 2,4-D containers and any other 2,4-D contaminated waste water. The concentrated 2,4-D wastes that will require treatment include any surplus, contaminated, partially or fully degraded pesticides.

The processes recommended for the treatment of dilute 2,4-D wastes at National Disposal Sites are:

Process	Order of Preference	Remarks
Activated-Carbon Beds	First Choice	Demonstrated technology on commercial scale; also adequate for removal of the sodium salt and esters of 2,4-D and most other types of pesticides from waste water.
Ion Exchange	Second Choice	Demonstrated technology; requires neutralization to the sodium salt first and not adequate for the removal of the 2,4-D esters from water.
Biological Degradation	Third Choice	Demonstrated technology on commercial scale, requires dilution with municipal sewage before treatment in aerated lagoons and stabilization ponds.

The processes for the treatment of concentrated 2,4-D wastes at National Disposal Sites are:

Process	Order of Preference	Remarks
Incineration	First Choice	Demonstrated technology; applicable to the disposal of organic pesticide wastes; possibility of recovering chlorine in the form of usable hydrogen chloride.
Soil Surface Application	Second Choice	Demonstrated technology; also applicable to the disposal of other types of herbicides that are degradable by soil microorganisms.

It should be noted that the activated-carbon bed and biological degradation processes could also be employed in the treatment of other types of dilute aryloxalkylcarboxylic acid wastes, such as 2,4,5-T and MCPA wastes. To dispose of other types of concentrated aryloxalkylcarboxylic acid wastes, because of the lack of supporting data on soil surface application, incineration is the only recommended process.

Example

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

The wastes generated in the manufacture and use of carbon disulfide can best be handled and treated at the site of generation by incineration or recycling. Incineration should be available at the National Disposal Site where the industry generating the waste has a special problem or can not handle the specific problem safely.

The findings of each Profile Report with respect to treatment categories and preferred treatment techniques are tabulated and presented in the appendix of Volume I.

Disposal Process Descriptions. Process Descriptions were prepared for the common waste treatment processes currently utilized. The general methods available for the disposal/recovery of hazardous wastes were categorized into physical treatment, chemical treatment, biological treatment, and ultimate disposal processes. Table 2 lists the 45 basic waste treatment techniques that are currently employed in pollution abatement, under the four separated categories.

It was felt that detailed descriptions of all the 45 processes listed were not warranted, and that only certain processes should be selected in preparing the "Process Descriptions". The bases for the selection were:

(1) The process should be one that is applicable to the treatment of hazardous wastes.

(2) The process should be one that is a candidate process for National Disposal Site utilization (not a municipal or common industrial type).

(3) The process should be a major unit treatment component. Pretreatment processes and add-on facilities for subsequent treatment should not be included.

(4) Processes that are standard chemical engineering unit operations and are applicable to a wide variety of other uses should not be included.

(5) Chemical treatment processes that are not "equipment oriented" should not be included.

Although all the 45 processes listed satisfied (1) and (2), (3) eliminated all the liquid-solid separation processes and the gas cleaning processes. In addition, (4) eliminated most of the other physical treatment processes, with the exception of dialysis, electrodialysis and reverse

TABLE 2

CLASSIFICATION OF WASTE DISPOSAL/RECOVERY PROCESS

Physical Treatment Processes					
Gas cleaning	Liquid-solids separation	Removal of specific components	Chemical Treatment Processes	Biological Treatment Processes	Ultimate Disposal Processes
Mechanical Collection	Centrifugation	Adsorption	Absorption	Activated Sludge	Deep Well Disposal
Electrostatic Precipitation	Clarification	Crystallization	Chemical Oxidation	Aerobic Lagoons	Dilute and Disperse
Fabric Filter	Coagulation	Dialysis	Chemical Precipitation	Anaerobic Lagoons	Incineration
Wet Scrubber	Filtration	Distillation	Chemical Reduction	Spray Irrigation	Ocean Dumping
Activated Carbon Adsorption	Flocculation	Electrodialysis	Combination and Addition	Trickling Filters	Sanitary Landfill
Adsorption	Flotation	Evaporation	Ion Exchange	Waste Stabilization Ponds	Land Burial
	Foaming	Leaching	Neutralization		
	Sedimentation	Reverse Osmosis	Pyrolysis		
	Thickening	Solvent Extraction			
		Stripping			

osmosis. The reason for (5) was that most chemical treatment processes involved the use of different chemical reagents in the treatment of specific types of wastes, and were better dealt with when discussing the disposal/recovery of individual wastes.

Using the five criteria cited here, 15 processes were selected. Table 3 lists these 15 processes and sites the volume and page numbers where each Process Description appears in this report. The following is a brief description of the format generally utilized in the preparation of the Process Description.

Introduction:	Includes a general description of the conventional process complete with flow diagram.
Operation Principle:	Presents a discussion of the underlying physical principles or chemical mechanisms for removal or transformation of the wastes.
Process Design:	Describes the auxiliary equipment used in the process and the loading parameters controlling the design and operation of the process. The range of normal operating conditions (e.g., temperature, pressure, pH, value) is also discussed.
Process Economics:	Briefly discusses the capital and operation costs for waste treatment and the major factors determining these costs.
Process Modifications:	Describes the common variations of the disposal process.
Process Applicability:	Presents a discussion of the general types of wastes that are or may be treated by the process as well as the applicability of the process to National Disposal Sites.

TABLE 3

PROCESS DESCRIPTION LOCATIONS

Process Category	Process Description	Volume No.	Page No.
Ultimate Disposal Processes	Deep Well Disposal	III	1
	Land Burial	III	19
	Landfill Disposal	III	45
	Ocean Dumping	III	69
	Incineration	III	99
Biological Treatment Processes	Activated Sludge	IV	1
	Aerated Lagoons	IV	27
	Oxidation Ponds	IV	43
	Trickling Filters	IV	55
Physical Treatment Processes	Dialysis	IV	69
	Electrodialysis	IV	91
	Reverse Osmosis	IV	129
	Radioactive Waste Solidification	IV	145
Chemical Treatment Processes	Pyrolysis	III	291
	Ion Exchange	IV	113

The general conclusions and recommendations reached in each Process Report, with respect to hazardous waste constituent application and National Disposal Site utilization, are presented in tabular form as Table 4.

TABLE 4

PROCESS DESCRIPTION CONCLUSIONS

Process Description	Conclusions and Recommendations
Deep Well Disposal	The use of deep well disposal techniques at National Disposal Sites should be limited to those waste stream constituents which have low toxicity in themselves and which also do not have breakdown or expected reaction products demonstrating high toxicity. This recommendation is based primarily on the apparent lack of control over wastes following injection. Without proper and adequate monitoring techniques the migration of hazardous materials from the "storage" area may not be detected until there is an effect on the non-storage area (ground water contamination, etc.) when it might be too late. Furthermore, given that an unexpected migration is detected there are currently no tested procedures which will reverse the migration or allow total recovery of the materials, or seal the periphera to insure halting the migration.
Land Burial	Land burial is a possible choice for National Disposal Site utilization for those hazardous materials that require complete containment and permanent disposal. This includes radioactive wastes as well as highly toxic chemical wastes. Disposal can be accomplished by either near-surface or deep burial. Deep burial is more applicable to the highly toxic or dangerous materials since better isolation from the biosphere is afforded. The important criterion in evaluating a particular land burial process is determining the integrity of the site. Sites with a life expectancy of a few hundred years are not applicable to wastes with a life expectancy of a few thousand years. In addition, before any land disposal methods can be selected, it must be determined if eventual retrieval of the wastes is required. This could be required if new reprocessing techniques are devised or under emergency conditions.

TABLE 4 (CONTINUED)

PROCESS DESCRIPTION CONCLUSIONS

Process Description	Conclusions and Recommendations
Landfill	The utilization of landfill procedures for the disposal of certain hazardous waste materials at a National Disposal Site, in an industrial environment, or in municipal application will undoubtedly be required in the future. In order to ensure that no damage to man or the environment results from this technique it is recommended that all sites currently used or proposed for the landfill disposal of hazardous wastes be subjected to stringent design procedures. It is further recommended that any site considered as a National Disposal Site be subjected to the analyses whether it is expected that landfill will be a primary disposal mode at that site or not since account must also be taken of possible accidental spillage of materials which represents an unintentional but direct application of the landfill technique.
Ocean Dumping	The utilization of ocean dumping for disposal of hazardous waste stream constituents is not currently recommended. Further research with specific wastes is required to determine the necessary additional information on the effects of the wastes on the ocean environment. The effects of the ocean environment on the wastes to be dumped must also be determined to ensure that toxic materials are not formed as the result of reaction and interaction. Finally, research is necessary to develop waste forms stabilized to ensure compatibility with the ocean environment on both short and long term bases.

TABLE 4 (CONTINUED)

PROCESS DESCRIPTION CONCLUSIONS

Process Description	Conclusions and Recommendations
Incineration	Some form of incineration capability will undoubtedly be required at all disposal facilities. The particular incineration process utilized is dependent upon the waste being treated at a given facility. Fluidized Bed Incinerator. The fluidized bed incinerator is generally applicable to the ultimate disposal of combustible solid, liquid and gaseous wastes; a significant advantage over most other incineration methods. For that reason, it is probable that this type of incineration unit would find application at National Disposal Sites, especially considering its suitability to the disposal of sludges. Rotary Kiln Incinerator. The rotary kiln incinerator is generally applicable to the ultimate disposal of any form of combustible waste material and represents proven technology. It can incinerate combustible solids (including explosives), liquids (including chemical warfare agents), gases, sludges and tars. For that reason, it is very likely that a National Disposal Site would contain a large industrial type rotary kiln incinerator. The National Disposal Site facility would require the addition of highly efficient secondary abatement such as scrubbers and precipitators. Multiple Hearth Incinerator. The multiple hearth incinerator is generally applicable to the ultimate disposal of most forms of combustible wastes and represents proven technology. It can incinerate combustible sludges, tars, granulated solids, liquids and gases and is especially well suited to the disposal of spent biological treatment facility sludges. For that reason, a disposal facility, especially one which contained biological treatment facilities, could contain a multiple hearth unit.

TABLE 4 (CONTINUED)

PROCESS DESCRIPTION CONCLUSIONS

Process Description	Conclusions and Recommendations
Incineration (Continued)	Liquid Waste Combustors. Liquid waste incinerators are generally applicable to the ultimate disposal of most forms (including dilute) of combustible liquid waste materials and represent proven technology. Because of their versatility, it is likely that some form of liquid waste incinerator would be an integral part of a National Disposal Site incineration system.
	Multiple Chamber Incinerator. Multiple chamber incinerators are generally applicable to the ultimate disposal of most forms of combustible solid waste and represent proven technology. Some of the materials currently disposed of in this type of unit are general refuse, paper, garbage, wood, phenolic resins, rubber, wire coatings, acrylic resins, epoxy resins, and polyvinyl chloride. Although the multiple chamber incinerator is capable of handling various types of solid wastes, its unsuitability to process liquids, gases, sludges and tars limits its application. Since there are other types of incineration units available which are much more diverse in application (i.e., rotary kiln fluidized bed and multiple hearth incinerators), it is doubtful that the multiple chamber incinerator would be a primary candidate for National Disposal Site utilization.
	Catalytic Incinerator. Due to the form of waste material to be treated (dilute and in the gaseous state) catalytic incineration is best suited for use at the processing site where the waste material is generated. Catalytic incineration would find use at a National Disposal Site only as a secondary treatment (i.e., afterburner) on primary treatment processes evolving varying amounts of miscellaneous hydrocarbons, alcohols, amines, acids, esters, aldehydes and many other contaminants which are basically hydrocarbon in nature. These materials have varying degrees of toxicity and different odor levels; however, they all lend themselves to catalytic

TABLE 4 (CONTINUED)

PROCESS DESCRIPTION CONCLUSIONS

Process Descriptions	Conclusions and Recommendations
Incineration (Continued)	oxidation. Generally, the commercial catalysts available for installation in operations which emit compounds of this kind are not specific. That is, they tend to oxidize all combustible organic compounds in the stream regardless of their type and concentration. Catalysts are also effective in the reduction of oxides of nitrogen and in burning sulfur bearing compounds such as hydrogen sulfide and carbon bisulfide. Direct Flame Combustor. Due to the form of the waste material being treated (dilute and in the gaseous state) direct-flame combustors are best suited for use at the processing site where the waste is generated. Direct-flame combustors would find use at a National Disposal Site as a secondary treatment (i.e., afterburner) on primary treatment processes evolving varying amounts of combustible contaminants. They are also well suited to the purification of ventilation air or any air which is monitored for pollutant control. Open Pit Incinerator. A variety of wastes have been burned in the pit incinerator. It readily accepts heavy timbers, cable reels and construction wastes. It burns plastics and similar high heat-release materials that might detonate, or erode the refractory in a closed unit. It effectively handles numerous types of manufacturing and process wastes both liquid and solid, plant trash and rubber wastes. Although the open pit incinerator is currently used industrially, it is not recommended for use at a National Disposal Site because of the associated lack of effluent control. This lack of control might result in emissions to the surroundings of harmful combustion products such as chlorides, fluorides, cyanides, sulfur compounds, carbon monoxide, or any partially combusted waste material.

TABLE 4 (CONTINUED)

PROCESS DESCRIPTION CONCLUSIONS

Process Description	Conclusions and Recommendations
Incineration (Continued)	Open Burning. Open burning is not considered to be an adequate form of waste disposal because of the associated loss of gaseous effluent control. Although open burning is currently utilized for the disposal of explosives and explosive wastes, it is anticipated that this practice will cease when new technology is developed for this application. Flares. Flares are generally applicable to the ultimate disposal of large volumes of combustible gases and aerosols. They have found application in most petroleum refineries and petrochemical plants. However, flares are not recommended for use at National Disposal Sites because of the associated lack of effluent control. This lack of control might result in emissions to the surrounding of harmful combustion products such as chlorides, fluorides, cyanides, sulfur compounds, carbon monoxide and any partially combusted or uncombusted waste material. Additionally, the form of waste handled by industrial flares (concentrated gases in large volumes) suggests that flares are best suited for use at the processing sites where the waste gas is generated.
Pyrolysis	Although the pyrolytic converter is a versatile piece of equipment that can be operated under varying conditions with various feed materials, its auxiliary equipment tends to be specific for various feeds and desired end products. For that reason, the overall pyrolytic process tends to lack versatility. At a National Disposal Site, a pyrolysis unit would probably find little direct application as a hazardous waste conversion unit. However, if sufficient refuse was generated at the site, a pyrolysis unit could be utilized to convert it into fuel gas for use in other operations (furnaces, incinerators, reboilers, boilers for steam production and possible subsequent conversion to electricity, etc.) and coke which could be utilized for its heat content or converted to activated carbon for use in water treatment facilities.

TABLE 4 (CONTINUED)

PROCESS DESCRIPTION CONCLUSIONS

Process Description	Conclusions and Recommendations
Activated Sludge Process	Although the activated sludge process is probably not applicable to the direct treatment of hazardous wastes in National Disposal Sites, installation of the process with a proper analytical monitoring system is recommended for treating all the process waste water (spent cleaning solutions, incinerator scrubber waste liquor, and cooling water) generated within the National Disposal Site to ensure no release of pollutants to the environment. The activated sludge process is most adaptable for treating biodegradable organic wastes with influent BOD_5 less than 3000 mg/l. Due to the sensitivity of the process to surges in waste loads, however, it is recommended that the process waste water be partially pretreated in trickling filters to stabilize the reaction of the activated sludge process to surges in loading.
Aerated Lagoons	The limitations on the BOD removal efficiency will probably circumvent the use of aerated lagoons as a single waste treatment unit where high quality effluents are specified. At National Disposal Sites handling hazardous wastes, it is recommended that the installation of aerated lagoons be considered only under the following circumstances. (1) as an interim treatment process that will be later converted to an activated sludge unit or; (2) as an "equalization tank" preceding other treatment units in a multistage biological treatment facility or; (3) as a "polishing pond" following other treatment units in a multistage biological treatment facility.

TABLE 4 (CONTINUED)

PROCESS DESCRIPTION CONCLUSIONS

Process Description	Conclusions and Recommendations
Oxidation Ponds	At National Disposal Sites treating hazardous wastes, it is recommended that oxidation ponds be considered for installation as a polishing stage for effluents from other biological waste treatment processes. Because of the complexity and possible toxicity of the incinerator scrubber waste liquors, spent cleaning solution wastes and spill control system wastes which possibly will be handled at a National Disposal Site, a multistage biological treatment system involving trickling filter - activated sludge - oxidation ponds will probably be required on effluent water streams. Such biological treatment would follow the removal of toxic inorganic components from the streams.
Trickling Filters	The complexity of industrial organic wastes and the stringent specification of effluent qualities have at times circumvented the use to trickling filter systems as a single stage treatment unit. At National Disposal Sites for the disposal of hazardous wastes, it is recommended that trickling filters be installed as a roughing device and the first stage in a multistage biological treatment facility. For example, systems can be designed with high rate trickling filters in series with the activated sludge process, to take advantage of the trickling filter's ability to handle shock loads and the ability of the activated sludge process to produce an effluent of high quality, and thus eliminate some of the shortcomings of each.

TABLE 4 (CONTINUED)

PROCESS DESCRIPTION CONCLUSIONS

Process Description	Conclusions and Recommendations
Dialysis	Dialysis is a suitable means of separation for any materials on the hazardous materials list which form aqueous solutions, e.g., inorganic salts such as ammonium chromate, or acids and bases such as phosphoric acid and sodium hydroxide. It is particularly suitable where high solute concentrations are involved, since reverse osmosis is then inapplicable and electrodialysis requires large energy inputs and concomitant high cost. Its inherent passivity, however, makes it inefficient where concentrations of feed or product solutions are much below 0.1 percent. With regard to acids and bases, dialysis does not require neutralization prior to treatment, as reverse osmosis does. But no dialysis membranes presently available are suitable for both acids and bases. With regard to National Disposal Site application, dialysis could most effectively be used for the further concentration of concentrated waste streams of extreme pH. The waste would then be stored or recycled for recovery.
Electrodialysis	Electrodialysis is applicable when it is desired to separate out a variety of ionized species from an unionized solvent such as water. In this regard, it might prove advantageous over reverse osmosis, where different species may interfere with one another, or dialysis, where the relative diffusivities and activities of the species play an important role. Ionizable nitrates and phosphates (e.g., $Pb(NO_3)_2$, $Hg(NO_3)_2$, $Na_3 PO_4$) are removed with varying degrees of efficiency. With regard to National Disposal Sites, electrodialysis is applicable for the treatment of waste streams where it is desirable to reduce the concentrations of ionizable species in the intermediate range (10,000 ppm to 500 ppm) over a broad range of pH (e.g., pH 1 to 14). Such streams may be comprised of combustor scrubber liquors, for example, or they may be the effluents from

TABLE 4 (CONTINUED)

PROCESS DESCRIPTION CONCLUSIONS

Process Description	Conclusions and Recommendations
Electrodialysis (Continued)	another treatment process which handled a stream of much higher concentration (e.g., dialysis). If an effluent of concentration lower than 500 ppm is desired, the electrodialysis effluent could be fed into another treatment process such as ion exchange. Its applicability to unionized organic species is effectively nil.
Ion Exchange	Ion exchange technology can be employed to remove, concentrate, and immobilize all of the metallic and non-metallic ionic species listed by the United States Public Health Service as toxic or undesirable when present in concentrations above certain levels. There are, for example, ion exchange techniques for removing the following potentially undesirable species from water and waste streams; iron, aluminum, manganese, copper, zinc, chromium, silver, nickel, cobalt, cadmium, barium, uranium, radium, mercury, lead, fluorine, boron, nitrates, phosphates, arsenic, sulfides, phenol, chlorophenols, glucose, and glycerine. With regard to National Disposal Sites, ion exchange could be used in conjunction with other concentrating processes. The main purpose of ion exchange at the Site would be to concentrate and remove specific hazardous wastes from various waste forms prior to long-term storage or recycling.
Reverse Osmosis	Reverse osmosis is an appropriate method for concentrating wastes on the hazardous materials list which form ions in aqueous solution, e.g., ammonium chromate. Also, organic materials of large molecular weight, such as dyes or bacteria, which dissolve or form suspensions in water are readily separable. Materials whose rejections by reverse osmosis are very poor are mainly low molecular weight organic compounds which do not ionize in aqueous solution, e.g., ethanol or urea. As a general rule,

TABLE 4 (CONTINUED)

PROCESS DESCRIPTION CONCLUSIONS

Process Description	Conclusions and Recommendations
Reverse Osmosis (Continued)	materials which are marginally soluble or insoluble are not appropriate, since their precipitation clogs the membrane. With regard to National Disposal Site application, reverse osmosis could be used for concentrating scrubber liquors, as might originate from combustors. The waste could then be further concentrated by evaporation, for example, prior to long-term storage or recycling to the supplier.
Radioactive Waste Solidification	The low-level radioactive waste solidification processes are applicable to National Disposal Sites since they utilize those wastes that are currently disposed of by direct burial in the ground. In general, these solidification processes are more adaptable to the short-lived isotopes (6 months to 30 yr) and less hazardous materials. The source of these types of wastes are the secondary streams generated at nuclear power plants and fuel reprocessing facilities, along with the wastes resulting from research laboratories and medical and industrial applications of radioisotopes. Cement, asphalt, and polyethylene are used for the solidification of these types of wastes.

5. DETERMINATION OF FORMS, SOURCES, AND QUANTITIES OF HAZARDOUS WASTES

The need to ensure that National Disposal Sites will have the capability and capacity to properly treat candidate waste stream constituents in the forms in which they would be sent there requires the determination of: (1) the actual forms of the hazardous materials in the appropriate waste streams; and (2) the quantities of the various waste forms on a national basis, and wherever possible, on a regional basis. Recognizing that the necessary information was not available in the literature or from the previous contract, the TRW program was expanded to include this additional effort.

It was beyond the scope of the study to attempt to determine the forms and quantities of every hazardous waste in a sufficient level of detail to be useful. Since the need to limit the scope was realized from the early beginning, the initial effort in this part of the program was to identify the hazardous waste stream constituents which merit intensive study. The general guidelines that have been employed in this selection task were similar to those developed for the identification of candidate waste stream constituents requiring treatment at National Disposal Sites. For each hazardous material, considerations were given to its degree of toxicity, the probability of its presence in sizable quantities as a solid, semi-solid, or concentrated liquid waste, and the complexity of the treatment that is required in its disposal/recovery. Utilizing the preliminary findings in the TRW program as a basis, and the additional information supplied by discussions with industrial and consultant contacts, the following were identified as hazardous waste stream constituents whose waste forms and quantities information would have the greatest potential impact on the design of future National Disposal Sites:

(1) Pesticides--including inorganics, organic arsenicals,
organochloro and organophosphorus compounds;

(2) Mercury and mercury compounds;

(3) Arsenic and arsenic compounds;

(4) Cadmium and cadmium compounds

(5) Lead compounds;

(6) Soluble copper compounds;

(7) Selenium and selenium compounds;

(8) Boron hydrides;

(9) Chromium compounds;

(10) Inorganic cyanides;

(11) Hydrofluoric and fluoboric acids;

(12) Specific organic chemicals--acrolein, dimethyl sulfate, chloropicrin, pentachlorophenol, and polychlorinated biphenyls;

(13) Explosives;

(14) Chemical warfare and riot control agents.

Radioactive wastes were not considered in the additional effort since an inventory of AEC generated wastes were contained in the Booz-Allen report. Radioactive wastes stored at Agreement State sites are being estimated from data obtained from the Kentucky State Department of Public Health.

The information derived is summarized in the remainder of this section and is presented in detail in Volume XIV.

Sources of Hazardous Wastes

Before the bulk of the information on the forms and quantities of hazardous wastes could be assembled through industrial, consultant, and governmental contacts, it was important to first determine the principal sources of these hazardous wastes. The data base on the particular hazardous waste stream constituents selected for this study, and specifically, the Booz-Allen report,[1] the California State Department of Public Health reports,[2,3] the information obtained from the Rollins Environmental Services subcontract effort identifying the composition and types of hazardous wastes generally received by waste disposal firms, and the Joint

Logistics Commanders Inventory of Obsolete Conventional Munitions, were extensively reviewed. The results of this investigation indicated that the sources of hazardous wastes could be broadly classified as: (1) manufacturing industry, (2) end users of finished products, (3) industrial, regional Environmental Protection Agency, and Department of Defense storage facilities.[4]

Hazardous waste stream constituents are found in manufacturing wastes due to their presence in the raw material, their application in the commercial production of other materials, or chemical conversions from raw, intermediate or finished products. The type of hazardous wastes generated by the manufacturing industry may include contaminated rags and packaging material, sludges, filter residues, fly ash and flue dust, tars from still bottoms and reactors, process solutions, contaminated solvents, wash and rinse water, and off-quality products. For the identification of the sources of these hazardous wastes, the hazardous waste stream constituents were correlated with the waste sources by industry* or government agency and this information was summarized in tabulated form (Table 5).

Hazardous wastes are generated by the end users of finished products as the products containing hazardous materials are replaced or as the containers with residual amounts of hazardous material are discarded. Examples of hazardous wastes generated as the result of product replacement include old batteries, control instruments, and fluorescent tubes that contain mercury, and old heat exchanger equipment, capacitors and transformers that contain polychlorinated biphenyls. Examples of hazardous residue wastes include pesticide and toxic paint residues left in used containers.

There are also large quantities of hazardous wastes stored in government and industrial facilities awaiting disposal. These include surplus pesticides, arsenic trioxide, pentaborane, other excess hazardous chemicals,† obsolete or overage conventional munitions, and surplus chemical warfare

---

*Correlation of waste sources by Standard Industrial Code (SIC) is usually too general.

†Excess hazardous chemicals in Department of Defense storage facilities; mostly compounds used in metal plating such as chromates, chromic trioxide, and cyanides.

TABLE 5

SOURCES OF HAZARDOUS WASTES BY INDUSTRY OR GOVERNMENT AGENCY

Industry and Government Agency	Hazardous Waste Stream Constituents
Pesticide manufacture	Pesticides
Pharmaceutical manufacture	Mercury
Paint and allied products manufacture	Cadmium, chromium, lead, mercury selenium
Sodium dichromate manufacture	Chromium
Petroleum production	Organic lead
Organic chemical industry	Copper, organic lead, acrolein, dimethyl sulfate, chloropicrin, pentachlorophenol, polychlorinated biphenyls
Explosive manufacture	Explosives
Phosphoric acid production	Arsenic
Smelting and refining of metals	Arsenic, cadmium
Chlor-alkali plants	Mercury
Battery manufacture	Cadmium, lead, mercury
Metal plating and finishing	Cadmium, chromium, copper, cyanides, fluoboric acid
Stainless steel pickling	Hydrofluoric acid
Copper pickling	Copper
Printed circuit production	Copper
Xerox drum manufacture	Arsenic, selenium
Leather tanning industry	Chromium
Textile industry	Chromium, copper
Department of Defense	Explosives, riot control agents, chemical warfare agents.

materiel. Surplus pesticides have been accumulated as the result of cancellation of registrations and certain use patterns. In the case of arsenic trioxide, there is currently a very limited demand for this compound, and a satisfactory, economical disposal method has yet to be developed. The pentaborane was produced under government contracts more than ten years ago for research in rocket fuels, and has been in storage since this application was terminated. Obsolete and overage conventional munitions scheduled for disposal are in the custody of the U. S. Army and U. S. Navy, at various military stations throughout the continental United States. Chemical warfare materiel declared surplus by Executive Directive is under the cognizance of the U. S. Army.

General Methodology

The approach taken to obtain information on the forms and quantities of hazardous wastes depends on the source of the waste material. For those wastes that are generated by the manufacturing industry or government agencies, the sources of data came from: (1) consultants, (2) industrial contacts, (3) government contacts, and to a much lesser degree, (4) existing literature. The consultants employed included a large waste disposal firm, Rollins Environmental Services, which provided information on the forms and composition of industrial hazardous waste streams generated in the New York, Pennsylvania, New Jersey and Delaware region and in the Gulf Coast region. Direct contacts with individual plants generating the hazardous wastes have provided additional information on the forms and composition of industrial hazardous waste streams, as well as most of the information on the quantities of industrial hazardous waste streams.* These contacts were normally established through telephone interviews and written communications, although field visits were conducted to paint and pesticide manufacturing plants, sanitary landfill disposal sites, and commercial waste disposal facilities. The government agencies contacted for information on industrial hazardous waste streams included the U. S. Army Munitions Command, the Joint Logistics Commanders Panel of the Department of Defense, the California

---

*Some of the information provided was of indirect nature, such as the percentage of arsenic present in phosphate rocks used in the production of phosphoric acid.

State Department of Public Health and the California State Water Resources Control Board.

For hazardous wastes that are generated by the end users of finished products containing hazardous constituents, the forms of the waste streams are normally the used or residual product and do not require further definition. Information on the quantities of these hazardous wastes was generally not available directly from any source. However, the data required for estimating the waste quantities, such as production volume and application areas of the hazardous waste stream constituents, were readily obtained from the published literature.

For hazardous wastes stored in industrial and government facilities, the sources of data were primarily the individual plants where the particular hazardous wastes were stored, the U. S. Environmental Protection Agency, the Joint Logistics Commanders Panel, the Munitions Command, and the U. S. Defense Supply Agency.

Estimation of Total Hazardous Waste Quantities. The limitation of time for this study precluded the survey of every plant in the country that produces the industrial hazardous waste streams of interest. The strategy to develop the waste forms and quantities information for the identified industrial hazardous waste streams was therefore to personally contact as many plants in each major waste source category as necessary to provide a meaningful, representative "waste production factor".* The number of plants contacted to obtain the required data ranged from one+ to over thirty for each industrial hazardous waste stream investigated.

The waste production factors are multipliers which can be applied to either the production or the consumption figure of a particular industry for the estimation of the total quantity of hazardous wastes generated.

---

*The TRW study was based on data obtained directly from industrial and consultant sources. The previous Booz-Allen study was based on survey of available literature.

+When the plant is the sole source of a hazardous waste stream--in which case there is no need to derive a waste production factor.

Therefore, the waste production factors are expressed either as quantity of hazardous waste generated per unit production volume or as quantity of hazardous waste generated per unit hazardous material consumed. The first type of waste production factor is used when the hazardous waste stream constituent may also be the principal product or a by-product, and when the hazardous waste volume is directly related to the production capacity of the plant. The second type of waste production factor is used when part of the hazardous material intended for consumption at a plant is lost in the application or production process and becomes a constituent of the waste stream from the plant, and is also used when the production capacity of a plant is difficult to define. Examples of the first type of waste production factor included pound of toxic paint sludge generated per pound of paint produced, and pound of mercury loss through brine sludges per ton of chlorine produced. Examples of the second type of waste production factor included pound of cadmium loss per pound of cadmium consumed by the electroplating industry, and pound of copper loss per pound of copper consumed by the printed circuit industry.

The waste production factors were normally obtained by dividing the quantity of hazardous waste generated by the production or consumption capacity of the plant. The total quantity of each hazardous waste stream (or the total quantity of the hazardous constituent released into the environment through that stream) was computed by multiplying the total production or consumption figure for the industry by the corresponding waste production factor.

For hazardous wastes that are generated by the end users of finished products containing hazardous constituents, the methods used to estimate the total quantities of hazardous wastes are separately discussed under the individual reports on each hazardous waste constituent in Volume XIV since a general method of computation was not applicable.

For hazardous wastes stored in industrial and government facilities, information on the waste forms, quantities, and locations were reported and there was no need for estimates. In the case of the information reported by the Department of Defense on surplus pesticides, excess chemicals, and munitions awaiting disposal, the listings were lengthy and it was necessary to compile and summarize the data before these could be presented in a comprehensive form in Volume XIV.

Geographic Distribution of Hazardous Wastes. The geographic distribution of the hazardous wastes investigated are generally presented in terms of the standard U. S. Regions as identified by the Bureau of Census.* Where the locations of the facilities producing hazardous wastes were not known, estimates of the waste distribution were based on: (1) regional production activity if the hazardous waste is generated by the manufacturing industry;† and (2) regional consumption volume if the hazardous waste is generated by the end users of finished products which contain hazardous constituents.

For each industrial sector identified with a hazardous waste stream, there were two types of methods to measure the regional production activity. When the production capacities and the locations of the plants generating the hazardous wastes were known, distribution of the total hazardous wastes was computed from the total production capacity in each U. S. Bureau of Census region. This was usually the case when the hazardous waste stream under investigation was generated by only a few major plants in the country. The second type of measure for regional production activity was the value added by the manufacture.‡ The value added by manufacture is derived by subtracting the total cost of materials from the value of shipments and other receipts, and adjusting the resulting amount by the net change in finished products and work-in-process inventories between the beginning and end of the year. The value added factor is considered by the Department of Commerce to be the best value measure available for comparing the relative economic importance of manufacturing among industries and geographic areas. The regional value added figures for each industrial sector were most useful for computing the distribution of hazardous wastes generated by industries that are composed of a large number of smaller plants, such as the electroplating industry.

---

*With the exceptions of pesticide waste distributions, which are presented in terms of USDA regions, and explosive wastes distributions which are presented by state.

†It was also assumed that technology within an industry is homogeneous and does not change according to geographic location.

‡The "value added by manufacture" figures were only used to complete the geographic distribution of the hazardous wastes. These figures are given in terms of each major SIC category (and for each state) and would not be useful for the estimation of the total quantity of any specific waste stream.

Generally, the quantity of a hazardous waste stream generated in a region by the end users of the finished product containing the hazardous constituent is proportional to the quantity of the finished product consumed in that region. For most cases, the regional consumption is also proportional to the regional population, and the population distribution was used to compute the geographic distribution of the hazardous wastes. Where more specific information was available a more exact and detailed approach was used as, for example, the regional pesticide use pattern was used to give a more accurate geographic distribution of the type of pesticide residue wastes left in used pesticide containers.

Summary of Findings

The specific assumptions and the methods of estimation used in the determination of the forms and quantities of hazardous wastes, along with detailed discussions of the sources, forms, composition, quantities and the geographic distribution of these wastes, are included in Volume XIV. A brief summary of the findings on each hazardous waste streams constituent investigated is presented below.

Pesticide Wastes. The three principal types of pesticide wastes from pesticide manufacturers and formulators are: (1) solid wastes containing 0.1 to 10 percent active ingredients on rags, bags, paper, fiber drums, steel drums, filter solids, etc.; (2) contaminated solvents containing 1 to 10 percent active ingredients and inert carriers in aqueous or organic solutions; and (3) process solutions that may contain up to 50 percent active ingredients, decomposition products, undesired by-products, etc. It is estimated that 200 million lb of pesticide contaminated solid wastes, 20 million lb of pesticide contaminated organic solvents, and 10 million lb of pesticide process solutions are generated each year by the pesticide manufacturing industry. The amount of active pesticide ingredients lost through these hazardous waste streams is approximately 3 million lb per year.

The total number of pesticide containers of all sizes requiring disposal in 1970 were computed to be in excess of 199 million. Of these, approximately 30 million are liquid pesticide containers which pose the greatest disposal problem. The total quantity of pesticide active ingredients left in the empty containers has been estimated to be 870,000 lb in 1970.

Sizable quantities of surplus pesticides have been accumulated in government facilities. The quantity of surplus pesticides currently in storage in Department of Defense facilities in the continental United States awaiting disposal amounts to 10 million lb, including 8.2 million lb phenoxy herbicides, 1.4 million lb polychlorinated hydrocarbon insecticides, and 140,000 lb organophosphorus insecticides. The quantity of surplus pesticides currently under the custody of the regional Environmental Protection Agency offices and requiring disposal amounts to 1.8 million lb. In addition, there are also 25,000 55-gal drums of 2,4-D and 2,4,5-T manufacturing by-product wastes stored at Alkali Lake, Oregon.

Mercury Wastes. The principal sources of mercury wastes in solid, semi-solid, or concentrated liquid forms have been identified as: (1) brine sludges from mercury cell chlor-alkali plants; (2) waste sludges from paint manufacturers; (3) paint residue left in used paint containers; (4) mercury used in electrical apparatus, industrial and control instruments, etc. that are not currently recycled. Mercury wastes from pharmaceutical and battery manufacture have been found to be insignificant.

The constituents of the brine sludges from mercury cell chlor-alkali plants include barium sulfate, calcium carbonate, calcium sulfate, magnesium oxide, magnesium hydroxide, graphite, some iron, aluminum, mud, rocks, and typically 100 ppm mercury in the form of $HgCl_4^=$. An estimated 16,500 lb of mercury are lost through 57,000 tons of brine sludges per year.

Phenyl mercury compounds are still used as mildewcides in water-based paints. The waste sludges from the latex washing system in paint manufacture typically contain 15 percent pigments, 20 percent binders, 65 percent water, and 100 to 150 ppm mercury. It is estimated that 1,800 lb of mercury are lost through 26 million lb of water-based paint sludges per year.

The paint residues left in used containers discarded in municipal dumps often contain 0.02 to 0.10 percent mercury. It is estimated that as much as 32,700 lb of mercury are lost through these paint residues per year.

Of the mercury used for other potentially recyclable uses, such as electrical equipment, measurement and control apparatus, and general laboratory uses, approximately 1 million lb per year (in batteries, fluorescent tubes, switches, etc.) are disposed of in landfills, dumps and incinerators.

Arsenic Wastes. The principal sources of arsenic wastes have been identified as: (1) flue dust from coal combustion; (2) flue dust from metal smelters; (3) production of food grade phosphoric acid; (4) pesticide residues left in used containers; and (5) miscellaneous forms of arsenic contaminated material, arsenic trioxide, and surplus arsenic pesticides in storage.

An estimated 85 million lb of arsenic trioxide are produced from coal combustion every year. The fraction of this amount that is currently being trapped by particulate removal systems is not known, but is expected to approach the above figure as tighter emission standards are enforced.

The amount of arsenic containing flue dusts recovered from the smelting of copper, lead, zinc, and other arsenic-bearing ores is estimated to be 80 million lb per year. The flue dusts normally contain 30 percent arsenic trioxide, along with mineral oxides, silica, and other materials. The amount of arsenic trioxide recoverable from metal smelting is therefore 24 million lb per year.

Nearly all phosphate rocks contain arsenic to some extent. As a result, phosphoric acid contains arsenic as an impurity and must be treated by sulfide precipitation to yield the food grade product. A typical waste stream from this purification process contains 8 percent arsenic sulfide, 7 percent activated carbon, 29 percent filter aid, 35 percent phosphoric acid, and water. Approximately 40,000 lb of arsenic waste (as arsenic sulfide) are generated in the manufacture of food grade phosphoric acid per year.

The major organic arsenicals used as pesticides include cacodylic acid, and the mono- and di-sodium salts of methane arsonic acid. The amount of these organic arsenicals left as residues in pesticide containers is estimated to be about 35,000 lb per year.

Miscellaneous arsenic wastes in storage awaiting proper disposal or treatment include: (1) a stockpile of 40 million lb of crude arsenic trioxide at American Smelting and Refining Company, Tacoma, Washington; (2) 16,000 lb of still bottom residues containing 15 percent arsenic stored in 55-gal. drums at Aerojet General Corporation, Sacramento, California; (3) 60 million lb of solid wastes containing sodium chloride, sodium sulfate, and 1 to 1.5 percent cacodylate contaminants stored in concrete vaults at Marinette, Wisconsin; (4) 12 tons of lead arsenate at Los Angeles Chemical Company, Los Angeles, California; (5) 34,000 lb of calcium arsenate, lead arsenate, copper acetoarsenite and other inorganic arsenic pesticides under the control of the Environmental Protection Agency and the Department of Defense.

Cadmium Wastes. The principal sources of cadmium wastes have been identified as: (1) rinse water and dragout from the electroplating industry; (2) waste sludges from paint manufacture; (3) paint residue left in used paint containers; and (4) wash water from the manufacture of nickel-cadmium batteries.

The electroplating industry is the largest user of the cadmium metal and is at the present also the largest source of cadmium wastes. The cadmium wastes are generated primarily as the result of the rinsing operations, and the typical aqueous waste stream contains 100 to 500 ppm cadmium, along with other heavy metals, cyanides, and metal surface cleaning agents. Large volumes of liquid waste streams having a much higher cadmium content, however, have also been reported. An example of such a waste stream contains 1.5 percent cadmium cyanide, 8.5 percent sodium cyanide, 3 percent sodium hydroxide, and traces of other metals. The total amount of cadmium wastes as cadmium from the electroplating industry has been estimated to be 1.44 million lb per year.

Cadmium wastes are generated in paint manufacture as a result of the kettle washings and equipment cleanup. The two most important cadmium pigments are the cadmium sulfide and the cadmium sulfoselenide. Cadmium in these forms are found in the solvent-based waste paint sludges, which typically contain 27.5 percent pigments, 25.0 percent binders, and 47.5 percent organic solvents. It is estimated that 5,100 lb of cadmium are lost through 37 million lb of solvent-based paint sludges per year. An additional estimated 35,000 lb of cadmium are lost as paint residues left in used paint containers each year.

The major source of cadmium waste in the manufacture of nickel-cadmium batteries (sintered-plate type) is the wash water that is used to remove excess material from the plates. The typical waste water effluent contains cadmium hydroxide, potassium hydroxide, and potassium nitrate, often in fairly high concentrations due to the cost of the deionized water normally used. Cadmium loss as cadmium from battery manufacture amounts to 3,700 lb per year.

Lead Wastes. The principal sources of lead wastes of concern have been identified as: (1) waste sludges from petroleum refineries; (2) waste sludges from the manufacture of alkyl lead compounds; (3) waste solvent-based paint sludges from paint manufacture; (4) paint residue left in used paint containers; (5) waste sludges from the manufacture of lead acid batteries; and (6) solvent and water washes from printing ink production.

Lead wastes from petroleum refineries are mainly the sludges from the storage tanks of leaded gasoline. A typical sludge contains a 1 percent mixture of tetraethyl lead and lead oxide, along with gasoline hydrocarbons, iron oxide, and silt. Total quantity of tetraethyl lead sludges from this source is estimated to be 4,800 tons per year.

Organic lead sludges are also generated from the manufacturing process for alkyl lead compounds. The sludge contains an average of 0.5 to 1.0 percent tetraethyl and teteramethyl lead. Annual production of this waste sludge is estimated to amount to 260 tons.

The major lead containing pigments include white lead, red lead, leaded zinc oxide, chrome green, chrome yellow, chrome orange, and molybdate orange. Lead is present in these pigments as the oxide, the carbonate, the hydroxide, the chromate, and the molybdate. In paint manufacture, lead is found in the waste solvent-based paint sludges which typically contain 27.5 percent pigment, 25.0 percent binders, and 47.5 percent organic solvents. It is estimated that a total of 640,000 lb of lead are lost through 37 million lb of solvent-based paint sludges per year. In addition, an estimated 4.4 million lb of lead are lost as paint residues left in used paint containers each year.

Lead wastes from the manufacture of lead acid batteries are generated as a result of the mixing operation of the lead acid pastes and the application of these pastes to support grids. It is estimated that over 1.3 million lb of lead, mostly in the form of lead sulfate in neutralized sulfuric acid, are lost through the waste sludges from battery manufacture each year.

Lead wastes from printing ink production are generated as a result of the operations to clean up the ball mills, mixing tanks, and other equipments. The waste is in the form of a liquid containing 0.5 to 1.5 percent lead pigment mixed with varying amounts of other metals in organic solvents and water washes. It is estimated that 21,000 lb of lead are lost through this waste stream each year.

Soluble Copper Wastes. Soluble copper wastes are of particular concern because of their high degree of toxicity to aquatic organisms. The principal sources of soluble copper wastes have been identified as: (1) rinse water and dragout from the electroplating industry; (2) etching solution wastes from printed circuit production; (3) spent copper catalysts; (4) copper pickling liquor; and (5) waste water from the textile industry.

Copper wastes from the electroplating industry come from several sources, but the most important of these is the rinse water. A typical waste stream has soluble copper concentrations in the range 50 to 10,000 ppm, alkaline concentrations from 1 to 20 percent as sodium hydroxide, along with some cyanides, chromium, nickel, and lead. It is estimated that there are 2.1 million lb of copper lost in the waste streams from the electroplating industry each year.

Copper wastes from the printed circuit production are generated mainly in the etching process where the copper not comprising the circuit is chemically removed from the circuit board. The waste is generally characterized by a high concentration (1,000 to 50,000 ppm) of soluble copper. The other constituents present in the waste depend primarily on the type of etchant used. Ferric chloride is the major etchant material, but cuprous chloride, ammoniacal chlorite, ammonium persulfate, and chrome/sulfuric solutions are also used. It is estimated that 460,000 lb of copper are through the waste streams from printed circuit production each year.

The chemical industry generates 600,000 lb of copper wastes (as copper) in the form of sludges each year by discarding spent copper catalysts. The composition of the sludge depends on the type of copper catalyst used and the particular segment of the chemical industry utilizing it. A typical waste sludge from aniline production contains 27 percent cuprous-cupric chloride tar in 65 percent mixed organics. The latter is mostly diphenyl ether.

Copper wastes are generated from the acid pickling of copper largely as a result of dragout of liquor from the pickling vats and the dumping of the vats when the acid strength is depleted. The typical waste stream from the pickling area contains 0.5 to 1 percent soluble copper, largely as copper sulfate when sulfuric acid is used. The total amount of copper waste generated from the pickling of copper is estimated to be 8.4 million lb (as copper) annually.

Copper wastes from the textile industry are generated mainly in the dyeing and finishing of cotton cloth. Wastes from these operations are extremely variable in contaminating matter, although the copper is usually found in the form of copper sulfate, copper ammonium fluoride, and copper ammonium carbonate. It is estimated that 6 million lb of copper are lost through the waste streams from the textile industry annually.

Selenium Wastes. Selenium is not found in significant quantities as wastes. One source of selenium waste that has been identified is in the manufacture and reconditioning of xerox drums. Selenium wastes generated from these operations each year include: (1) about 700,000 lb of solid wastes containing cotton linter, steel, aluminum, and 300 to 400 lb of selenium and arsenic; and (2) 50,000 lb of liquid waste consisting primarily of caustic solutions and 0.3 percent selenium and arsenic.

Selenium as cadmium sulfoselenide is also found in paint wastes. However, it is estimated that only 370 lb of selenium are lost in the waste solvent-based paint sludges from paint manufacture each year, and an additional 2,600 lb as paint residue left in used paint containers.

Boron Hydride Wastes. The only source of diborane wastes is the residual gas remaining in the manifolds when the diborane gas is diluted with argon, nitrogen, or hydrogen for sale. The total quantity of this gaseous waste containing an average of 100 ppm diborane is estimated to be less than 2 cu ft per year.

Pentaborane is no longer being manufactured. There is, however, a stockpile of 20,000 lb of pentaborane at Edwards Air Force Base, California. Current consumption of pentaborane amounts to only 50 to 75 lb per year.

Decaborane is a high-valued material and all decaborane containing streams are normally recycled in the manufacturing process. The only source of decaborane waste is the several pounds of decaborane contaminated solid wastes generated each year from its production.

Chromium Wastes. The principal sources of chromium wastes in solid, semi-solid, or concentrated liquid form have been identified as: (1) rinse water and dragout from the metal finishing industry; (2) filter residue from sodium dichromate manufacture; (3) waste sludges from paint manufacture; (4) paint residue left in used paint containers; and (5) surplus chemicals under the custody of Department of Defense. In addition, significant amounts of chromium compounds in highly diluted forms (ppm level) are also lost through the waste waters from the textile industry, the leather industry, and from the blowdown of cooling towers.

In the metal finishing industry, hexavalent chromium compounds are formulated for use as cleaning agents, oxidizing agents, surface preparation agents, as well as the chemicals used to electroplate the decorative chrome surface. The wastes are generated from the extensive washing of the metal parts as well as spills, tank leakages, and the periodic draining of the metal treatment tanks. The composition of the wastes varies widely but the chromium levels (present mostly as hexavalent chromium) are normally between a few ppm and a few percent. Other constituents present in the wastes may include copper, zinc, cadmium, nickel, cyanides, grease, oils, acids, organic additives, and cleaning agents. The amount of chromium compounds discharged through the waste streams from the metal finishing industry is estimated to total 62 million lb (calculated as sodium dichromate) per year.

Chromium wastes from sodium dichromate manufacture are generated in the processing of the chromium ores. The waste consists primarily of a gangue residue containing about 4 percent trivalent chromium as Cr_2O_3 (dry weight basis), and some iron, aluminum, and calcium in varied forms depending on the process employed. Approximately 18 million lb of chromium (as Cr_2O_3) are lost as wastes from sodium dichromate manufacture each year.

The major chromium containing pigments include chrome green, chrome oxide green, chrome yellow, chrome orange, zinc yellow, and molybdate orange. With the exception of chrome oxide green (Cr_2O_3), all the other chromium pigments contain chromium in the hexavalent form and are normally only used in solvent-based paints. It is estimated that a total of 140,000 lb of chromium are lost through 37 million lb of waste solvent-based paint sludges each year, and a total of 10,000 lb of chromium lost through 26 million lb of waste water-based paint sludges each year. An additional estimated 1 million lb of chromium are lost as paint residues left in used paint containers each year.

Chromium compounds under the custody of Department of Defense and awaiting disposal include 34,200 lb of anhydrous sodium chromate, 3,000 lb of potassium dichromate, 2,000 lb of chromium trioxide, and smaller quantities of potassium chromate and sodium dichromate dihydrate.

Cyanide Wastes. The principal source of cyanide wastes is the electroplating industry. Cyanide compounds are used extensively to make up the plating baths because they serve as good complexing agents. Waste streams from the electroplating industry contain varying amounts of cyanides ranging from 0.5 to 20 percent, normally in an alkaline solution along with cadmium, copper, zinc, nickel, and chromium compounds. It is estimated that 21 million lb of cyanides are discharged through electroplating wastes each year.

The less toxic ferrocyanide is a component of the iron blue and the chrome green pigments. Approximately 45,000 lb of cyanides are lost through the 37 million lb of waste solvent-based paint sludges generated each year. In addition, 310,000 lb of cyanides are lost as paint residues left in used paint containers each year.

Cyanide compounds in Department of Defense storage facilities awaiting disposal include sodium, calcium, copper, silver, and potassium cyanides, but amount to less than 2,000 lb total.

Hydrofluoric and Fluoboric Acid Wastes. The principal sources of hydrofluoric acid waste* are the spent pickling solutions and the rinse water from the stainless steel pickling process. The pickling waste typically contains 1 to 2 percent hydrofluoric acid, along with sulfuric acid, nitric acid, iron salts, and traces of other metals such as chromium, nickel, and cobalt. Approximately 200 million lb of stainless steel pickling wastes containing 2.8 million lb of hydrofluoric acid are generated each year.

The principal source of fluoboric acid waste is the rinse water from metal plating. The aqueous waste effluent normally contains 1 to 2 percent of fluoboric acid, traces of lead, tin and other metals and acids. It is estimated that 14,000 lb of fluoboric acid are discharged through metal plating waste streams each year.

Wastes of Specific Organic Chemicals. Of the five hazardous organic chemicals investigated, the polychlorinated biphenyls (PCBs) are the only compound(s) which can be found in sizable quantities as wastes. Acrolein wastes are generated in insignificant quantities from its manufacturing process and from its usage. The only chloropicrin waste that has been identified is an aqueous effluent from the manufacturing process containing less than 0.01 percent chloropicrin along with 3 percent sodium hydroxide and 20 percent sodium chloride. The total chloropicrin loss from this waste effluent is estimated to be less than 1,700 lb per year. The principal dimethyl sulfate waste is a viscous dark brown still bottom liquid residue containing less than 1 percent dimethyl sulfate from its manufacturing process. The total still bottom waste generated per year is approximately 200,000 lb, with a dimethyl sulfate loss of less than 200 lb. Pentachlorophenol loss from its manufacturing process is also insignificant, and amounts to approximately 400 lb per year. In the main application as termite and mold controls on lumber products it is claimed that the wood treating process is carried out in a closed system and almost no waste effluent containing pentachlorophenol is generated.

---

*Other than the extremely dilute hydrogen fluoride discharges from the fertilizer industry.

Solid, semi-solid, and concentrated liquid polychlorinated biphenyl wastes are generated as equipments or products containing these chemicals are replaced and discarded. Although the current application of PCBs is restricted to confined systems (primarily as dielectric fluids for capacitors and transformers), PCB wastes continue to be generated from applications which were previously acceptable such as industrial fluids for hydraulic systems, heat transfer fluids, and plasticizers. It has been estimated that approximately 19,000 tons of PCBs (mostly Aroclor 1242) were disposed of in incinerators, dumps and landfills in 1970.

Explosive and Riot Control Wastes. The largest source of explosive and riot control agent wastes is the Armed Services' obsolete conventional munitions scheduled for disposal. The hazardous materials contained in obsolete conventional munitions have been divided into six classes for convenience. The amounts at U. S. Facilities awaiting disposal as of November 30, 1972 of each of these six classes, and the weight of the obsolete conventional ordnance items in which they are contained are as follows:

(1) initiating agents and primers--305,000 lb (in 150,487,000 lb gross weight munitions);

(2) propellants, nitrocellulose based--37,822,000 lb (in 204,004,000 lb gross weight munitions);

(3) propellants, composite/other--1,000 lb (in 834,000 lb gross weight munitions);

(4) high explosives--38,775,000 lb (in 207,406,000 lb gross weight munitions);

(5) pyrotechnics and incendiaries--2,942,000 lb (in 46,783,000 lb gross weight munitions);

(6) riot control agents--1,018,000 lb (in 2,691,000 lb gross weight munitions).

The variety and number of waste forms for obsolete conventional munitions are very large. There are over 11,000 different Federal Stock Numbers for obsolete ordnance items in California alone, ranging from fuze components to artillery shells and from fractions of an ounce in weight to hundreds of pounds per item.

The hazardous wastes destroyed by explosive manufacturers are generally in two forms--either scrap explosive, or explosive-contaminated inert wastes. The weights of the hazardous materials and explosive contaminated inert wastes for five of the six classes above, subjected to disposal processing annually by the explosive and munitions manufacturing industry are:

(1) initiating agents and primers--304,000 lb per year(plus 4,018,000 lb per year contaminated inerts);

(2) propellants, nitrocellulose based--6,046,000 lb per year (plus 8,824,000 lb per year contaminated inerts);

(3) propellants, composite/other--1,756,000 lb per year (plus 333,000 lb per year contaminated inerts);

(4) high explosives--13,810,000 lb per year (plus 11,692,000 lb per year contaminated inerts);

(5) pyrotechnics and incendiaries--783,000 lb per year (plus 639,000 lb per year contaminated inerts).

The quantity of explosive manufacturing wastes given above does not include explosive wastes discharged to receiving water courses as dilute solutions or suspensions. Data on such dilute waste discharges is not available in sufficient depth to enable estimates on other than a very rough order-of-magnitude basis. The amount of dilute aqueous waste discharge of explosives, estimated on that basis, is less than 2,000,000 lb per year.

Information furnished to TRW by the California Department of Justice and a major riot control device manufacturer, indicates that there are no local government waste disposal requirements for overage of obsolete riot control devices/agents. Governmental law enforcement agencies (local) use all of the overage or obsolete devices for training exercises.

Chemical Warfare Agents. There is no information currently available for publication on the quantities of chemical warfare agents and material scheduled for disposal. The estimated quantities of salts which will be produced by the disposal of chemical warfare materiel is 70,000 tons. The salts will be mixtures of the chloride, sulfate, sulfite, fluoride, carbonate, phosphate, and methylisopropylphosphonate of calcium and/or sodium. There is no current official schedule available for disposal.

Radioactive Wastes. The records kept by the Kentucky State Department of Public Health have been transcribed onto computer compatible media as a first step in establishing an inventory of radioactive wastes stored in Agreement State sites. The Kentucky data itemizes the wastes stored at the Maxey Flats site (see discussion of Land Burial in Volume III). However, the computerized data have not been reviewed or analyzed to any significant degree at the present time (August 1973). Therefore, no quantitative data are presented.

6. RESEARCH AND DEVELOPMENT RECOMMENDATIONS AND PLANNING

An important aspect of this program was the identification of those specific areas within the hazardous waste management field where additional research and/or development activity is needed in order to bring current practice to an "adequate" level. In this chapter of the final report are summarized the results of the program efforts aimed at defining, planning, and outlining those research and development activities which are considered necessary for upgrading particular portions of current hazardous waste management technology to an acceptable status.

Major identified areas requiring research and development are discussed below together with a very brief description of specific recommended projects in each area. The identified areas include disposal of waste pesticides, stabilization of non-degradable inorganic toxic chemical wastes, utilization or ultimate disposal of hazardous solid wastes resulting from air and water pollution control, stabilization and ultimate disposal of radioactive wastes, reclamation of heavy metal contaminated soils and silts, removal of very low concentration of mercury and other hazardous heavy metals from aqueous waste streams, feasibility of ocean disposal of hazardous wastes, feasibility of landfill disposal of hazardous wastes, toxicological research on waste constituents and characterization of waste forms, quantities and source locations. Criteria for the prioritization of the recommended projects are presented together with recommended priorities and expenditure levels for specific problem areas and projects. In Volume XV are presented detailed R&D plans for many of the recommended projects. Results of proof-of-principle experimentation on selected problems in the hazardous waste field are also presented in Volume XV.

Major Identified Areas Requiring Research and Development

Disposal of Waste Pesticides. The disposal of pesticide wastes and containers contaminated by pesticide residues is one of the serious environmental problems that has caused growing concern in recent years. Large stocks of surplus pesticide wastes have been accumulated as a result of the cancellation of registrations, the production of off-specification material in pesticide manufacture, the degradation of pesticides from either long-term or improper storage conditions, and the cleaning of empty pesticide containers by rinsing. The total number of pesticide containers of all sizes in 1970 has been estimated to be almost 200 million. Of these, approximately 30 million are liquid pesticide containers which pose the greatest disposal problem.

For surplus pesticides and pesticide manufacturing wastes, conventional means of disposal such as deep-well injection and sanitary landfill without prior detoxification have been deemed inadequate because of potential pollution of land and water. At the present time, TRW has determined that controlled incineration at high temperatures followed by efficient scrubbing of the furnace gas effluent is the only satisfactory method for the disposal of bulk quantities of organic and metallo-organic pesticide chemicals in concentrated form.

It is recognized that a number of the incinerators currently in use for the disposal of industrial and municipal wastes are readily adaptable to the disposal of pesticide wastes. On the other hand, information on the combustion characteristics of pesticides is limited so that at present it is not possible to identify those existing incinerator installations that could be safely used for the disposal of pesticide wastes. In its investigation under the current contract, TRW has concluded that very little practical experimental data relating to the incineration of pesticides has been determined. There is a definite need to fill this gap in the technological base.

Used pesticide containers normally retain significant amounts of pesticide residues and the disposal of these "empty" pesticide containers constitutes another hazard associated with the widespread use of pesticides. The 30-gal. and 55-gal. metal drums may be shipped to cooperage facilities for reconditioning by direct flame burning. Such activities, however, are often not regulated and the adequacy of the decontamination procedures employed has not been closely examined. The smaller 1-gal. and 5-gal. metal containers and the 1-gal. glass containers, on the other hand, do not in general possess sufficient structural and thermal strength to warrant decontamination and reuse. These are usually disposed of in sanitary landfills, either with or without being previously rinsed and punctured or crushed. Again, there is a need for more information to define the extent of decontamination achieved by rinsing and to develop criteria for acceptable landfill sites. In the case of the small metal containers, the alternative solution of reducing the containers to smaller size nuggets by shredding followed by thermal incineration leads to the recovery of a valuable resource and merits being more fully explored. Combustible used pesticide containers include paper sacks, fiber drums, and plastic bottles and are most conveniently disposed of by incineration. However, the type of information needed to characterize pesticide incineration will also be required here to establish guidelines for approved incinerators.

Specific Projects. As can be seen from the foregoing discussions, many of the questions regarding the safe disposal of pesticide wastes and empty pesticide containers remain unanswered. To provide the answers to these questions, it is recommended that the following research and development studies be carried out:

(1) Characterization of Incineration Parameters for the Safe Disposal of Pesticides

This project will characterize pesticide incineration to the degree necessary for incinerator selection, develop qualification procedures for incinerators suitable for pesticide disposal, and identify and test incinerator installations throughout the country for safe pesticide disposal. Details of the project are presented in Volume XV.

(2) Development of New Chemical Concepts for Utilization of Waste Pesticides

This program will include the development of thermochemical and chemical kinetic models of the behavior of a broad range of representative pesticides in high temperature combustion and/or coreactant environments, the identification of waste pesticide/coreactant products of potential commercial value, and preliminary engineering and economic evaluation of processing approaches for waste pesticide utilization. Project details are presented in Volume XV.

(3) Investigation of the Technical and Economic Feasibility of Setting up a Network of Collection Centers, Storage Sites, Decontamination Stations, Reclamation Plants and Approved Landfill Disposal Sites for Used Pesticide Containers

This program will also include the development of procedures to guarantee adequacy in the implementation of the used pesticide container management system.

(4) Investigation of the Technical and Economic Feasibility of Recycling Noncombustible Used Pesticide Container Material

This project will include pilot scale testing of shredded container material to determine the degree of decontamination attainable by proper thermal incineration.

Stabilization of Nondegradable Inorganic Toxic Chemical Wastes. Ultimate disposal of solid waste materials and sludges which contain toxic, nondegradable inorganic compounds such as those of mercury, arsenic, cadmium, chromium, lead, etc., present a major problem. It is essential in the ultimate disposal environment that these highly toxic and nondegradable wastes be effectively isolated and not allowed to disperse significantly. It would be very desirable to stabilize and agglomerate heavy metal containing wastes to the point where their long-term rate of dispersion (by leaching, etc.) in an ultimate disposal environment (e.g., landfill) is no greater than the existing rate of dispersion of the naturally occurring ores. How to accomplish adequate passification of heavy metal containing wastes and still remain within economically acceptable boundaries is, of course, the key problem. It is recommended that major emphasis on research programs in this area be aimed at identifying the lowest cost techniques which will:

(1) Convert the heavy metals into their least soluble compounds (sulfides, oxides, etc.).

(2) Agglomerate the sludges containing "least soluble" heavy metal compounds into leach-resistant solid "clinker" material.

(3) Coat the "clinker" material (if necessary) with resins which will totally isolate the heavy metal compounds from aqueous leachants.

Specific Projects.

(1) Development of Low Cost Cementation Approaches to Passification of Heavy Metal Sludges and Solids

A number of concepts for stabilizing and agglomerating solid wastes and sludges containing heavy metal compounds were identified and several approaches were briefly investigated in the laboratory. Further laboratory development and economic assessment of the most promising approaches is recommended. A detailed description of this project is presented in Volume XV.

Utilization or Ultimate Disposal of Hazardous Solid Wastes Resulting from Air and Water Pollution Control. It is anticipated that the dramatically increased controls on air and water pollution planned for the near future will have a major effect on the solid waste management field. A marked decrease in the discharge of industrial wastes to the air, inland waterways, and oceans must necessarily result in large new accumulations of solid wastes or sludges. For example, control of the 30 million tons per year of sulfur dioxide which is currently discharged into our atmosphere from fossil fuel burning power plants will result in greater than 60 million tons per year of calcium sulfate-fly ash solid waste if the limestone-slurry technique of SO_2 stack scrubbing is adopted.* This resulting solid waste material from the limestone scrubbers is expected to contain potentially leachable hazardous trace metal constituents of the fossil fuels such as mercury and beryllium compounds.

It is very likely that there will be many other examples of new solid waste management problems which will occur as a result of increased air and water pollution controls. It is recommended that a systematic investigation be initiated, on an industry-by-industry basis, aimed at identifying the nature and magnitude of these problems. As specific problems are identified, the research and development needs in each area should be detailed and projects initiated on a timetable which is consistent with the application of new air and water pollution legislation and controls.

Specific Projects.

(1) Identification of Hazardous Solid Waste Management Problems Created as a Result of Air and Water Pollution Controls

This project will separately investigate each major industrial classification† and determine the probable forms, quantities, and disposal or reuse operations associated with new solid wastes which would be created as a result of:

1. Industry-wide application of the best air and water pollution control technology currently practiced within the industry.

2. Industry-wide application of the best available air and water pollution control technology.

---

*Currently the leading approach.

†The program will probably best be handled as a series of sub-projects, each assigned to a different industry.

3. Industry-wide application of the best new air and water pollution control technology including processes which are still in the development or demonstration stages.

(2) Development of a New Process for the Economic Utilization of the Solid Waste Effluent From Limestone Slurry Wet Scrubber Systems

A new process was conceived for utilizing the $CaSO_4$-$CaSO_3$-fly ash solid waste effluent from sulfur oxide wet scrubbing systems. The solid effluent can be economically utilized in the extraction of alumina from low grade domestic ores (clay). The process also produces cement (calcium silicates) and sulfur. This processing scheme results in the total utilization of the wet scrubber solid waste effluent and the sale of the products produced are expected to more than pay for the processing costs.

A Phase I program of bench-scale laboratory investigation and preliminary engineering design is recommended. A more detailed process description and project plan is presented in Volume XV.

Stabilization and Ultimate Disposal of Radioactive Wastes. Nearly all projections of this nation's energy requirements and sources over the next 20 to 50 years point to a tremendous increase in nuclear reactor generated power. The increase in nuclear generated power will, of course, result in a corresponding increase in high level radioactive fission product waste. It is anticipated that these reactor generated fission products will present the greatest hazardous waste management challenge in the near future.

The extreme hazard associated with these materials and lack of completely satisfactory disposal options makes fission product waste disposal a prime area for investment of research and development dollars. Awareness of the potential problems in the ultimate disposal of high-level radioactive wastes has spurred the Atomic Energy Commission to sponsor investigations into all the major aspects of high level radioactive waste management. Responsibility for this area is centered within the AEC's Division of Waste Management and Transportation (DWMT). Primary efforts at DWMT in order of decreasing emphasis are:

(1) Engineered surface storage facilities

(2) Salt mine pilot plant

(3) Assessment of long-term disposal methods

Since the major R&D planning activity associated with the ultimate disposal of high level radioactive wastes is being performed under the jurisdiction of the AEC, no specific projects in this area were considered under the current study. However, it is felt that the importance of this area, particularly in the future, must be very strongly emphasized and adequate R&D funding made available.

Concentration of effort on the stabilization and disposal of the more hazardous high-level wastes has diminished the attention placed on the disposal of low-level wastes (which in many cases are no longer a specific AEC responsibility) and the proliferating amount of these wastes requires an early effort aimed at their more careful control and more knowledge of their ultimate fate. Basically, what is required is an accurate knowledge of what material is being disposed of and what the long-term fate of that material is in the disposal environment. This information is necessary in order to select sites and site boundaries and predict the dose rate at the boundaries as a function of time.

Specific Projects in Low Level Radioactive Waste Management. The following paragraphs describe several specific projects recommended for further research and development in the area of low-level waste management.

(1) Development of Inventory Control Systems

Systems are needed whereby the type, quantity, location, etc., of waste disposed at each site are known. Work has already begun, under EPA sponsorship, to establish an inventory data system at the Morehead, Kentucky, low-level radioactive waste burial site, and it is anticipated that this system will be implemented at the other commercial burial sites. However, this system will rely on the material identification supplied by the originator of the waste. Such an approach leads to inaccurate information because of human error or intentional mislabeling of materials. It is also possible that the wastes submitted for disposal contain non-radioactive chemicals which affect the rate at which the radioactive elements leach into the soil. Some means of positively identifying the type of material and quantity received for disposal is required. A means of identifying each element is also required. It may be feasible to utilize conventional counting equipment and a computer program which identifies the material based on its energy spectrum. It is recommended that the feasibility of positively identifying at the burial site the types and quantities of materials for disposal be investigated.

(2) Investigation of the Long-Term Leaching of Low-Level Wastes

A percentage of the material deposited in trenches at a low-level waste disposal site will eventually leach into the soil and ultimately affect the radioactive dose rate at and beyond the site boundary. In order to be able to predict what that dose rate will be, it is necessary to gain more complete information on the mobility of radioactive waste materials in soils. It is recommended that a series of tests be conducted in which the behavior of typical low-level wastes in soils would be investigated. Both vertical and horizontal leaching tests should be included. Vertical permeation data would be useful in assessing the safety of a site located over a fresh-water source. Data on the horizontal permeation rate would be useful in selecting a site and establishing the site boundaries.

Reclamation of Heavy Metal Contaminated Soils and Silts. The fate, in soil environments, of heavy metal solid waste compounds containing mercury and arsenic is of national interest due to their potential for getting into animal and human food chains. One of the current goals of the Environmental Protection Agency is to eliminate the further dispersion of mercury compounds into the environment. Soils and silts from river bottoms, waste settling basins, and agricultural areas in several parts of the country are contaminated with mercury and arsenic compounds. Mercury concentrations as high as 560 ppm have been reported in the sediments from some lakes and rivers. Known sources of this potentially hazardous contamination are pesticide run-off, discharges from chlor-alkali plants, discharges from wood pulp and paper plants, and military waste basins. For example, Rocky Mountain Arsenal Basin A is known to contain approximately 1.3 million tons of lagoon bottom soil contaminated with mercury halides, arsenic oxides, arsenic chloride, and other inorganic chemicals. An inexpensive process for separating the heavy metal contaminants from soils is needed in order to eliminate the further dispersion of those hazardous pollutants into the environment.

Recommended Projects.

(1) Development of a Process for Gaseous Extraction of Mercury and Arsenic Compounds from Contaminated Soils or Silt

A gaseous extraction processing scheme was conceived which addresses itself to the above described problem of economically and selectively separating mercury and arsenic contaminants from soils or silts. Proof-of-principle experiments with samples of contaminated soil from the Rocky Mountain Arsenal were very encouraging. Starting with soil samples containing 40 ppm of mercury and 42 ppm of arsenic, 99.5 percent of the mercury and 70 percent of the arsenic were removed from the soil by the proposed technique.

A phase I project of laboratory bench-scale development and economic analysis is recommended. If successful, the Phase I activity would be followed by a pilot plant demonstration project. A detailed plan for this recommended project is presented in Volume XV together with a discussion of the results of proof-of-principle testing.

(2) Mercury and Arsenic Recovery from Contaminated Soils by Chemical Leaching

Several chemical leaching approaches to the separation of mercury and arsenic contaminants from soils showed promise in initial proof-of-principle testing. It is recommended that these approaches be further explored in the laboratory.

Removal of Very Low Concentrations of Mercury and Other Hazardous Heavy Metals from Aqueous Waste Streams. Elimination of the environmental dispersion of mercury and other heavy metal containing wastes is an Environmental Protection Agency goal. In order to meet this goal extremely effective, low cost, final polishing techniques for the removal from water of very low concentrations of mercury and other heavy metals are required. Currently available technology is either not sufficiently effective, or extremely expensive. A low cost technique for separating mercury compounds from water down to the 1-10 ppb level or better is needed.

Specific Projects.

(1) Application of Polysulfide Systems to the Selective Removal of Mercury and Other Heavy Metals from Water

New concepts for utilizing polymeric forms of sulfur (very low cost or even worthless waste materials) as complexing agents for separating mercury compounds (and other heavy metals) from water were briefly investigated in the laboratory. The thrust of the technical approach is to tailor polymeric sulfur compounds in order to make effective selected separation operations such as flocculation, ion exchange, or extraction. Very effective separations of mercury salts from water were demonstrated (<10 ppb) and it is recommended that a program of detailed laboratory investigation and engineering analysis be initiated. Results of the laboratory proof-of-principle experimentation and a specific project plan are presented in Volume XV.

Feasibility of Ocean Disposal of Hazardous Wastes. As mentioned earlier, the use of the ocean environment as a "catch-all" for the disposal of hazardous wastes was an important factor in stimulating interest in the whole question of adequate disposal of such wastes. In the course of the current study ocean disposal as an ultimate disposal technique was the subject of a process description. In preparing this description and in analyzing the possible application of the technique to various wastes, a number of areas were found where information necessary to the determination of criteria for the adequacy of ocean disposal was lacking. While there is no question that a disposal technique cannot be advocated without adequate assurance as to its safety, the adverse economics associated with the utilization of other disposal techniques for many wastes necessitates that the decision to eliminate recourse to ocean disposal should not be made permanent without much more extensive information than is currently available.

The analysis of ocean disposal made in the context of the current program has indicated a great lack of hard data on what might be acceptable ocean disposal. The hard data gaps fall into two general categories: 1) the information necessary on the effects both of waste materials on the ocean environment and of the ocean environment on the materials and 2) the information required to identify waste forms acceptable to the ocean environment.

Specific Projects. To fill the information voids cited, implementation of the following research and development studies are recommended:

(1) Determination of the Effects of Selected Wastes on the Ocean Environment

In this project, representative samples will be obtained from wastes currently disposed of in the ocean environment for which other disposal technology is not available or is totally impractical economically.

The representative samples will be used in laboratory experiments in large tanks of seawater to determine waste interactions at various dilution rates and ratios with seawater and to identify the effects of the wastes and their reaction products on representative marine animal, fish and plant life. The experimental apparatus will be used to follow the history of the wastes selected in the simulated ocean environment, and assist in determining their ultimate fate. The final phase of this project will include extensive field testing in ocean areas which have previously been well characterized in their normal unperturbed condition.

(2) Application and Field Test of Waste Stabilization Technology in the Ocean Environment

This project will encompass the application and testing in an ocean environment of selected stabilized wastes. The most stable waste forms developed in the previously discussed program on stabilization of nondegradable toxic wastes will be extensively evaluated in ocean field tests.

Feasibility of Landfill Disposal of Hazardous Wastes. Landfill disposal is one of the most extensively employed techniques used for both municipal and industrial waste disposal. This technique (the subject of a process evaluation in a later portion of this text) is based on the principle that, subsequent to disposal of a waste by landfill, the earth surrounding the waste will interact physically and chemically with the waste material to maintain its isolation from the vulnerable environment. Since there are no data to suggest that interactions do occur, the extent and form of the interactions are not well characterized. The extent of protection offered by landfill disposal is, therefore, not well understood.

Specific Projects. To provide the data needed for understanding the extent of protection offered by landfill disposal, the following research and development studies are recommended.

(1) Development of a Quantitative Landfill Characterization Model

This program will address, specifically, the construction of a suitable model, determination of the model parameters, and field testing of the model, as indicated in the brief discussion of a quantitative evaluation technique in the landfill disposal process evaluation (Volume III). The intent of the quantitative rating system will be to provide a basis for comparison between potential sites, and for determination of the suitability of individual sites for specific wastes.

(2) Application and Field Test of Waste Stabilization Technology in the Landfill Environment

This project will encompass the selection and testing of stabilized wastes in the landfill environment. The most stable waste forms developed in the program for stabilization of nondegradable toxic wastes covered earlier in this report will be extensively evaluated in landfill field tests, to enable accurate prediction of long term effects on the surrounding environment. The model developed above and the results of the field tests will be used to define waste forms which improve the "storage" capability of the landfill site by limiting the modes and rates of release of toxicants.

Toxicological Research on Waste Constituents. Criteria for defining adequate waste management for some 516 potentially hazardous waste stream constituents was recommended in this program. The criteria included a definition of the recommended provisional maximum allowable concentrations of waste constituents which can be released to air, water, and soil environments. Many of those recommendations were of necessity developed by extrapolation from a very thin data base. It is apparent from this study that there is an important requirement for the generation of additional toxicological data on many industrial waste materials. In particular a paucity of reliable data occurs in the area of chronic oral toxicity of the waste constituents in water. The following waste constituents, all of which have been designated as potential candidates for National Disposal Sites, are considered to be materials for which additional toxicological information is most needed:

Acrolein
Bromine pentafluoride
Carbonyl chloride
Chloroacetophenone
Copper chlorotetrazale
Decaborane
Detonators
Diazodinitrophenol
Diborane
Dimethyl sulfate
Dinitro cresols
Dinitrotoluene
Dipentaerythritol
Glycol dinitrate
Hydrazine azide/hydrazine
Lead 2,4 dinitroresorcinate
Lead styphnate
Nitrocellulose
Nitrogen mustard
Nitroglycerine
Pentaborane
Pentachorophenol
Picric acid
Potassium dinitrobenz furoxan
Silver acetylide
Silver azide
Silver tetrazene
Smokeless gunpowder
Sulfur mustard
Tetrazene

Characterization of Waste Forms, Quantities, and Source Locations. As noted in Chapter 5 "Determination of Forms and Quantities of Hazardous Wastes", the scope of the current study is limited to a one-time determination of the waste forms, quantities and source locations of hazardous waste stream constituents which merit intensive study. The data obtained, because of the restricted scope of the study and the scarcity of information in several extremely important areas, is limited to use for the gross prediction of hazardous waste management requirements in the immediate future. Due to the enormous variability with time of hazardous waste forms, quantities and source locations, some means for updating the data periodically, and for systematically interpreting the updated data is necessary for accurate, continued inventory and management of hazardous wastes by the Environmental Protection Agency. The following research and development study is recommended to develop the vehicle needed for updating and systematic interpretation of the various hazardous waste form data:

(1) Development of a Hazardous Waste Form, Quantity and Source Location Characterization Model

The study will develop a quantitative model for the characterization of hazardous material waste forms, quantities, and source locations encompassing the use of periodically updated data, to permit systematic interpretation and accurate prediction, as necessary for continued inventory and hazardous waste disposal management. To further development of the model and allow periodic updating, an expanded study will be made of information sources and an information system will be developed to meet the updating requirements of the model. A test updating of the various hazardous waste form data will be performed, and the model excercised thereon.

Criteria for Prioritization of Projects

In order to delineate the relative importance of the "problem areas" and "specific projects" which were recommended and outlined in the previous paragraphs, a system for prioritization was developed. The "problem areas" were first assigned weights for each of two pertinent criteria, and ranked as "critical", "important", or "desirable" in decreasing order of priority. The projects, arranged according to the "problem areas" were then divided into two classifications--"technology development projects" and "information gathering projects", to permit rating in accordance with their appropriate criteria. Each project was assigned a mathematical weight for each pertinent criterion. The sum of the mathematical weights for the project represented the relative net worth of the project. The relative importance obtained in this way was used to categorize the project. The rating assigned each project was, subject to the limitation imposed by the rating assigned the pertinent area of investigation, either "critical", "important" or "desirable" in decreasing order of priority.

Recommended "problem areas" were weighed against two criteria; (1) the magnitude of the environmental hazard involved, and (2) the paucity of pertinent information and/or applicable technology. Relative weighting scales of 0 to 6 were applied to each criterion. Overall "problem area" net worth required for each of the three priority categories was:

Critical = ≥ 9

Important = 6 - 8

Desirable = 3 - 5

As noted above, R&D project recommendations were divided into two classifications. Those projects which were classified on the basis of their work content and objectives as "information gathering projects" were assessed for weighting against four criteria, as follows:

(1) Importance of new data for assessing magnitude of environmental hazard. Relative weighting on a scale of 0 to 6.

(2) Importance of new data for assessing waste management technology. Relative weighting on a scale of 0 to 6.

(3) Importance of new data for assessing economic impact of pollution controls. Relative weighting on a scale of 0 to 3.

(4) Probability of obtaining significant data. Relative weighting on a scale of 0 to 3.

Overall information project net worth required for each of the three priority categories was:

Critical = ≥ 9

Important = 6 - 8

Desirable = 4 - 5

Projects which were classified as "technology development projects" were assessed for weighting against three criteria, as follows:

(1) Importance of environmental hazard reduction possible through new technology. Relative weighting on a scale of 0 to 6.

(2) Importance of economic benefits possible through new technology. Relative weighting on a scale of 0 to 3.

(3) Probability of successful technology development. Relative weighting on a scale of 0 to 6.

Overall technology development project net worth required for each of the three primary categories was:

Critical = ≥ 9

Important = 6 - 8

Desirable = 4 - 5

Assessment was in all cases made on the basis of individual judgement. The baseline (0 weighting) for the "probability of obtaining significant data" and "probability of successful technology development" criteria was set at 0.2. Projects with lower probabilities of success were deleted.

Recommended Priorities and Expenditure Levels for Research and Development

The "problem areas" and the specific research and development projects summarized in the prior portions of this section were assessed for priority assignment as detailed above. In addition to the categorization by priority, each project was analyzed to obtain an estimate of costs over a five-year span (Table 6).

The five-year expenditure breakdown shown is not an overall schedule recommending the order of project accomplishment; it is the estimate of individual project costs over the five-year period from whatever date is set for project start. Cost estimates were not extended to the full five-year span for those cases where there was currently insufficient data on which to base reasonable estimates, or where projects could be accomplished in the time span shown.

It will be noted that annual costs for some projects increase during the last year shown. This increase is in general due to the requirement in the final project phase, to evaluate the data from several preceding years of observation.

TABLE 6

PRIORITY RATINGS AND ESTIMATED COSTS FOR RECOMMENDED R & D PROBLEM AREAS & SPECIFIC PROJECTS

Problem Area	Specific Project	Rating*									Total	Priority	Five Year Cost ($Thousands)					
		A	B	C	D	E	F	G	H	I			Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
1. Waste Pesticide Disposal		4	5								9	Critical						
	Characterization of incineration parameters	-	-	4	5	2	2	-	-	-	13	Critical	250	300^{+}	300^{+}			850
	Chemical concepts for utilization of waste pesticides	-	-	-	-	-	-	4	1	0	5	Desirable	150					150
	Pesticide container collection and disposal system	-	-	-	-	-	-	4	-	5	9	Critical	200	100				300
	Recycle of noncombustible used pesticide container material	-	-	-	-	-	-	4	1	5	10	Critical	200					200
2. Stabilization of Nondegradable Inorganic Toxic Chemical Wastes		4	5								9	Critical						
	Development of low cost cementation approaches	-	-	-	-	-	-	4	-	4	8	Important	100	100	100			300
3. Utilization or Ultimate Disposal of Hazardous Solid Wastes from Air and Water Pollution Control		3	6	-	-	-	-	-	-	-	9	Critical						
	Identification of problems created as a result of air and water pollution controls	-	-	3	5	2	2	-	-	-	12	Critical	200	150				350
	Utilization of solid waste effluent from limestone slurry wet scrubber systems	-	-	-	-	-	-	3	3	3	9	Critical	150	400	750	750		2050

TABLE 6 - CONTINUED

PRIORITY RATINGS AND ESTIMATED COSTS FOR RECOMMENDED R & D PROBLEM AREAS & SPECIFIC PROJECTS

Problem Area	Specific Project	Rating* A	B	C	D	E	F	G	H	I	Total	Priority	Five Year Cost ($Thousands) Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
4. Stabilization and Ultimate Disposal of Radioactive Wastes		6	6	-	-	-	-	-	-	-	12	Critical						
	Development of inventory control systems	-	-	-	-	-	-	3	-	4	7	Important	150	150				300
	Investigation of the long-term leaching of low level wastes	-	-	4	2	-	1	-	-	-	7	Important	150	100	100	50	50	450
5. Reclamation of Heavy Metal Contaminated Soils and Silts		2	5	-	-	-	-	-	-	-	7	Important						
	Development of a gaseous extraction process for Hg and As	-	-	-	-	-	-	2	1	3	6	Important	100	200	500			800
	Recovery of Hg and As by chemical leaching	-	-	-	-	-	-	2	1	1	4	Desirable	100	200	500			800
6. Removal of Low Concentrations of Heavy Metals from Aqueous Waste Streams		3	3	-	-	-	-	-	-	-	6	Important						
	Application of polysulfide systems to selective removal	-	-	-	-	-	-	3	2	2	7	Important	150	150	150			450
7. Ocean Disposal of Hazardous Wastes		4	5	-	-	-	-	-	-	-	9	Critical						
	Effects of selected wastes on the ocean environment	-	-	4	5	5	3	-	-	-	17	Critical	150	200	300			650
	Field test of waste stabilization technology	-	-	-	-	-	-	4	2	3	9	Critical	100	200	50	50	100	500
8. Landfill Disposal of Hazardous Wastes		5	4	-	-	-	-	-	-	-	9	Critical						
	Development of a quantitative landfill characterization model	-	-	5	4	2	2	-	-	-	13	Critical	100	200				300

TABLE 6 - CONTINUED

PRIORITY RATINGS AND ESTIMATED COSTS FOR RECOMMENDED R & D PROBLEM AREAS & SPECIFIC PROJECTS

Problem Area	Specific Project	Rating* A	B	C	D	E	F	G	H	I	Total	Priority	Five Year Cost ($Thousands) Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
	Field test of waste stabilization technology	-	-	-	-	-	-	5	1	2	8	Important	100	250	50	50	100	550
9. Toxicological Research on Waste Constituents		2	3	-	-	-	-	-	-	-	5	Desirable	($40,000 to $80,000 per individual hazardous material)					
10. Characterization of Waste Forms, Quantities and Source Locations		5	5	-	-	-	-	-	-	-	10	Critical						
	Development of a hazardous waste form, quantity & source location characterization model	-	-	5	3	1	2	-	-	-	11	Critical	250	300	300	300	300	1,450

*Rating categories are as follows:

A = Magnitude of the environmental hazard involved
B = Paucity of pertinent information and/or applicable technology
C = Importance of new data for assessing magnitude of environmental hazard
D = Importance of new data for assessing waste management technology
E = Importance of new data for assessing economic impact of pollution control
F = Probability of obtaining significant data
G = Importance of environmental hazard reduction possible through new technology
H = Importance of economic benefits possible through new technology
I = Probability of successful technology development

† Facility certification costs

♦ U.S.A.E.C. Division of Waste Management and Transportation budget for research on disposal of high level radioactive wastes is $7,000,000 for FY 1973

7. CONCLUSIONS AND RECOMMENDATIONS

In the course of this study a very complete overview was acquired of the various factors influencing the proper management of hazardous wastes. Three categories of broad conclusions and recommendations have resulted from the investigations: (1) the requirement for National Disposal Sites; (2) the requirement for the control of hazardous wastes; and (3) the requirement for further research. Each of these categories are discussed below.

The Requirement for National Disposal Sites

National Disposal Sites are essential to adequate waste management for some wastes. In formulating the definition for a National Disposal Site presented in Chapter 3 and in deriving the criteria for the identification of candidates for treatment at those sites, a rather restrictive basis was utilized in order to avoid advocating an approach which would duplicate what is currently available. Despite this restrictive framework it is the conclusion of the TRW project team that a system of disposal sites meeting the definition provided in Chapter 3 is required. The need is defined most clearly in the cases of those waste stream constituents requiring permanent storage of some type to protect the public and/or the environment from the adverse effects of that material. Examples of such materials are the long-lived radioisotopes found in some nuclear wastes and the economically stagnant hazardous materials, such as, the arsenic trioxide recovered in metal refining processes. Other materials which require special handling and well monitored disposal practice, such as, pesticides, might conceivably be treated in industrial facilities. However, the current uncertainty in proper operating conditions for the incineration of the pesticides and the general lack of monitoring at the current disposal facilities precludes recommendation thereof, thus necessitating National Disposal Site treatment.

It is recommended, therefore, that a system of National Disposal sites meeting the definition provided earlier be established. While it is not necessary that these facilities be owned and/or operated by the government, it is required that their operation be carefully monitored by the government to ensure their function of protecting the public and the environment. To meet the requirement for handling those waste stream constituents designated as candidates for National Disposal Sites, a facility must, at the minimum, have unloading facilities, permanent storage facilities (land burial and/or landfill), an incinerator equipped to combust solids, liquids, and gases with adequate scrubbing and particulate removal to maintain emissions below the statutory limits, acid and base neutralization facilities, and chemical oxidative, reductive, and precipitative reactors for stabilizing sludges in their least toxic and least soluble forms. In addition, very complete monitoring of the effluents of the processes within the facility and of the facility itself are mandatory. At regular intervals reports should be made to the Federal Government from each National Disposal Site summarizing the monitor data, reporting the quantities, types, and sources of incoming wastes requiring treatment, and indicating their within-facility and final disposition. These reports would be interpreted for purposes of insuring compliance with various regulations and determining the need for the modification of operations.

The strict dependence of such facilities on government, particularly federal legislation and regulations, the requirement for extensive reporting to and monitoring by the government, and the possible scarcity of appropriate locations for economically servicing particular areas, suggests the establishment of a utility to ensure financing and avoid monopolistic business practice. Appropriate federal and state commissions would be required to regulate the site structures and ensure compliance with all regulations.

Control of Hazardous Wastes

Hazardous industrial wastes should be subject to strict accountability in their disposal. The system of National Disposal Sites advocated above is necessary to the proper management of some hazardous wastes, but it is not sufficient to ensure that all potentially hazardous wastes can not endanger the public. From many contacts with industry personnel made during the course of the study, it was concluded that adequate disposal processing often was not being applied to many of the waste stream constituents under investigation. This was the conclusion both for those constituents designated by our study as candidates for National Disposal Sites and also for many of the materials which can be properly treated by industrial or even municipal techniques. Many people with whom the management of industrial wastes was discussed would not answer questions as to their practice, indicating that they feared possible legal action. Often the same people indicated that they were aware of proper technology but that it was not applied generally, they said, because of cost. Many industrial contacts also indicated that hazardous wastes were being stored, often in open lagoons, until a proper disposal technique was identified.

While the larger manufacturers and users were usually aware of the general form of their wastes, the sources of the wastes, and the disposition of those wastes, many of the smaller manufacturers and users of hazardous materials considered in this study indicated that they had no idea what happened to the materials. They knew only that these materials required periodic replacement. These small producers may be inadvertently causing much undetected damage to the environment and possibly to public health.

It is our recommendation that a set of rigorous and uniform regulations and controls be formulated and applied to the disposal of all hazardous wastes. The following elements should be included in the regulations: (1) the requirement that the waste be chemically destroyed, converted to its least toxic and least soluble form and placed in suitable permanent storage facilities, or safely shipped to a facility which will perform those functions; (2) the requirement that records of the chemical composition, physical form, and disposition of all wastes containing hazardous constituents be maintained and submitted to EPA on a regular basis; (3) the requirement that plant effluents from storage and disposal areas be monitored to detect these hazardous constituents with maintenance and submittal of records; (4) a limit on the quantities of hazardous materials that can be stored in a hazardous form on a facility "awaiting" disposal; and (5) the requirement that the facilities be open to inspection by EPA personnel.

Hazardous wastes subjected to municipal disposal should be limited wherever possible. The control of hazardous industrial wastes addressed above covers those wastes generated from relatively few sources, such as, the industrial plants. The much broader problem is to determine control strategies operable in the consumer environment. At the present time almost all discarded items containing hazardous materials are subject to municipal disposal management which would not be adequate to preclude possible effects to the environment if the concentrations were high. Much larger volumes of many hazardous wastes are discarded in municipal facilities than in industrial facilities; for example, at least 20 times as much paint sludge containing lead, mercury, and other such compounds are in old paint cans rather than in the wastes from the paint industry. Two general control strategies which would limit possible dangers are (1) to encourage industry to utilize substitutes for the hazardous materials in consumer and other products which ultimately are subject to municipal disposal, and (2) to develop and utilize municiple disposal techniques which concentrate the hazardous wastes such that they may be properly handled or sent to a National Disposal Site or which stabilize the hazardous wastes such that the potential public and environmental exposure levels are below the provisional limits discussed in Volume II.

Required Research

The TRW recommendations as to specific areas requiring further research and proposed program approaches were provided in Chapter 6. As was stated there, each of these programs is necessary to the development of an information base or to development of an adequate disposal method for particular materials. These programs were necessarily limited to technological objectives since these had been emphasized in the TRW project. However, in the course of the program, another type of research with less immediate objectives was identified as important and necessary to adequate waste management. This additional research would be directed at determining the interactions of the government, industry, the public, and technology in formulating disposal/resuse strategies.

It is recommended that modeling studies be undertaken which will simultaneously consider the effects of various government policies on the use, recovery, and reuse of hazardous materials. Specific policies which would require consideration in the model are disposal control regulations, National Disposal Site fee structure, import/export regulation, depletion allowances, mining or manufacturing quotas, tax incentives, and subsidies. The modeling studies should provide economic (cost) and social (changes in labor patterns) tradeoffs on the substitution of non-hazardous materials for hazardous materials and the recovery of the hazardous materials from the discarded end item. Other factors, such as, increased or reduced pollution and conservation of natural resources (including, but not limited to, the hazardous material) must also be considered in constructing the models and in interpreting and providing the results. The complexity of these interactions requires a broad, quantitative approach to provide the information necessary to making decisions of best possible benefit to the public and the environment.

8. REFERENCES

1. Booz-Allen Applied Research Inc. A study of hazardous waste materials, hazardous effects and disposal methods, v. 1-3. Report prepared for the Environmental Protection Agency under Contract No. 68-03-0032, June 1972.

2. Golueke, C. G. and P. H. McGauhey. Comprehensive studies of solid waste management, second annual report. Washington U.S. Government Printing Office, 1970. 245 p.

3. Andres, D. R. and L. A. Barch. California solid waste planning study--hazardous waste disposal survey 1971. California State Department of Public Health, Jan. 1972. 69 p.

4. Defense Supply Agency. JLC Conus inventory, by location, of obsolete conventional munitions as of July 28, 1972. Joint AMC/NMC/AFLC/AFSC Commanders' Panel on Disposal Ashore of Ammunition.

APPENDIX

TABLE 7
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Acetaldehyde	1	Municipal Type Disposal	1.8	9.0	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Acetic Acid	2	Municipal Type Disposal	0.25	1.25	X	Concentrated: Controlled incineration. Dilute: Chemical or biological degradation via municipal waste treatment systems.
Acetic Anhydride	3	Municipal Type Disposal	0.20	1.0	X	Concentrated: Controlled incineration. Dilute: Reaction with water to form acetic acid followed by chemical or biological degradation via municipal waste treatment systems.
Acetone	4	Municipal Type Disposal	24	60.0	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Acetone Cyanohydrin	5	Industrial Disposal	0.45	1.99	X	Concentrated: Controlled incineration (oxides of nitrogen are removed from the effluent gas by scrubbers and/or thermal devices). Dilute: Biological treatment (highly dependent upon pH and temperature conditions); activated carbon treatment (as a polishing step to be used in conjunction with biological treatment).
Acetonitrile	6	Industrial Disposal	0.7	3.5	X	Concentrated: Controlled incineration (oxides of nitrogen are removed from the effluent gas by scrubbers and/or thermal devices). Dilute: Biological treatment (highly dependent upon pH and temperature conditions); activated carbon treatment (as a polishing step to be used in conjunction with biological treatment).

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Acetylene	7	Municipal Type Disposal	22	110	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture).
Acetyl Chloride	9	Municipal Type Disposal	.01	.05	X	Concentrated: Controlled incineration. Dilute: Reaction with water to form acetic acid followed by chemical or biological degradation via municipal waste treatment systems.
Acridine	464	Industrial Disposal	0.15	0.75	X	Concentrated: Controlled incineration whereby oxides of nitrogen are removed from the effluent gas by scrubber, catalytic or thermal device. Dilute: Oxidation by activated sludge; adsorption on activated carbon.
Acrolein	8	National Disposal Site	.0025	.01	VIII	Concentrated: Incineration (1500F, 0.5 seconds minumum for primary combustion; 2000F, 1.0 second for secondary combustion) - combustion products are CO_2 and water. Dilute: Secondary biological treatment after neutralization; submerged combustion (for concentrating the waste) followed by incineration.
Acrylic Acid	10	Municipal Type Disposal	.01	.05	X	Concentrated: Incineration. Dilute: Biodegradation with unacclimated activated sludges in municipal sewage treatment plants.
Acrylonitrile	11	Industrial Disposal	0.45	1.99	X	Concentrated: Controlled incineration (oxides of nitrogen are removed from the effluent gas by scrubbers and/or thermal devices). Dilute: Biological treatment (highly dependent upon pH and temperature conditions); activated carbon treatment (as a polishing step to be used in conjunction with biological treatment).

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Adipic Acid	12	Municipal Type Disposal	0.25	1.25	X	Concentrated: Incineration. Dilute: Biodegradation with unacclimated activated sludges in municipal sewage treatment plants.
Aldrin	13	National Disposal Site	.0025	.012	V	Concentrated: Incineration (1500F, 0.5 seconds minimum for primary combustion; 3200F, 1.0 second for secondary combustion) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated-carbon beds; chemical oxidation with potassium permanganate.
Allyl Alcohol	14	Municipal Type Disposal	0.05	0.23	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Allyl Chloride	15	Industrial Disposal	.03	0.15	X	Concentrated: Controlled incineration (1800F, 2 seconds minimum). Dilute: Controlled incineration (for dilute organic waste); hydrolized, then treated with acclimated activated sludge (for dilute aqueous waste).
Aluminum Fluoride	16	Industrial Disposal	.025 (as F)	0.6-1.7 (as F)	XII	Concentrated: Precipitation with soda ash or slaked lime - resulting sludge should be sent to a California Class 1 type landfill. The supernatant liquid is neutralized with dilute hydrochloric acid before being washed into a sewer or stream with large quantities of water.
Aluminum Oxide	465	Municipal Type Disposal	0.1	0.5	XII	Landfill in a California Class 2 type facility.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Aluminum Sulfate	17	Municipal Type Disposal	0.01 (as H_2SO_4	250 (as SO_4)	XII	Hydrolysis followed by neutralization with NaOH. The insoluble aluminum hydroxide formed is removed by filtration and can be heated to decomposition to yield alumina which has valuable industrial applications. The neutral solution of sodium sulfate can be discharged into sewers and waterways as long as its concentration is below the recommend provisional limit of 250 mg/l.
Aminoethylethanol Amine	18	Municipal Type Disposal	.06	0.30	X	Concentrated. Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Ammonium Bifluoride	544	Industrial Disposal	0.025 (as F)	0.6-1.7 (as F)	XII	Aqueous Waste: Reaction with an excess of lime, followed by lagooning, and either recovery or landfill disposal of the separated caclium fluoride. The supernatant liquid from this process is diluted and discharged to the sewer.
Ammonium Chloride	20	Municipal Type Disposal	0.10	250 (as Cl)	XII	Treated with sodium hydroxide to liberate ammonia and form the soluble sodium salt. The liberated ammonia can be recovered and sold. After dilution to the permitted provisional limit, the sodium salt can be discharged into a stream or sewer.
Ammonium Chromate	21	National Disposal Site	.001 (as CrO_3)	.05 (as Cr)	VI	Concentrated: Reduction/Precipitation with hydroxide ion. Dilute: Reduction/Precipitation; Ion Exchange.
Ammonium Dichromate	22	National Disposal Site	.001 (as CrO_3)	.05 (as Cr)	VI	Concentrated: Reduction/Precipitation with hydroxide ion. Dilute: Reduction/Precipitation; Ion Exchange.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Ammonium Fluoride	23	Industrial Disposal	0.025 (as F)	0.6-1.7 (as F)	XII	Aqueous Waste: Reaction with an excess of lime, followed by lagooning, and either recovery or landfill disposal of the separated calcium fluoride. The supernatant liquid from this process is diluted and discharged to the sewer.
Ammonium Hydroxide	19	Industrial Disposal	0.02	0.01	XII	Neutralization with nitric acid to form a solution of ammonium nitrate which can be used as fertilizer.
Ammonium Nitrate	24	Municipal Type Disposal	0.05	45 (as NO_3)	XII	Treated with sodium hydroxide to liberate ammonia and form the soluble sodium salt. The liberated ammonia can be recovered and sold. After dilution to the permitted provisional limit, the sodium salt can be discharged into a stream or sewer.
Ammonium Perchlorate	25	Industrial Disposal	0.01	0.05	XII	Dissolve the material in water and add to a large volume of concentrated reducing agent solution, then acidify with H_2SO_4. When reduction is complete, soda ash is added to make the solution alkaline. Ammonia will be liberated and will require recovery. The alkaline liquid is decanted from any sludge formed, neutralized, diluted and discharged to a sewer or stream. The sludge is landfilled.
Ammonium Persulfate	26	Industrial Disposal	0.01	0.05	XII	Dissolve the material in water and add to a large volume of concentrated reducing agent solution, then acidify with H_2SO_4. When reduction is complete, soda ash is added to make the solution alkaline. Ammonia will be liberated and will require recovery. The alkaline liquid is decanted from any sludge formed, neutralized, diluted and discharged to a sewer or stream. The sludge is landfilled.
Ammonium Picrate, Dry	27	National Disposal Site	.001 (as picric acid)	.005 (as picric acid)	VII	Concentrated: Incineration followed by adequate particulate abatement and wet scrubbing equipment. Dilute: Chemical degradation with sodium sulfide solution. The H_2S and NH_3 liberated must be scrubbed from the vent air.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Ammonium Picrate	28	National Disposal Site	.001 (as picric acid)	.005 (as picric acid)	VII	Concentrated: Incineration followed by adequate particulate abatement and wet scrubbing equipment. Dilute: Chemical degradation with sodium sulfide solution. The H_2S and NH_3 liberated must be scrubbed from the vent air.
Ammonium Sulfide	29	Industrial Disposal	0.15 (as H_2S)	0.75 (as H_2S)	XII	Converted into the insoluble ferrous sulfide by reaction with ferrous chloride solution. The ferrous sulfide precipitate may be removed by filtration and reclaimed.
Amyl Acetate (Banana Oil)	30	Municipal Type Disposal	5.3	26.3	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Amyl Alcohol (Fusel Oil)	31	Municipal Type Disposal	3.0	15	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Aniline (Oil-Amino Benzene)	32	Industrial Disposal	0.19	0.95	X	Concentrated: Controlled incineration whereby oxides of nitrogen are removed from the effluent gas by scrubber, catalytic or thermal device. Dilute: Oxidation by activated sludge; adsorption on activated carbon.
Anthracene	466	Municipal Disposal	0.5	2.5	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solution into the municipal sewers after primary treatment; incineration (for dilute organic mixture).

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Antimony	33	Industrial Disposal	0.005	0.05	XII	Wastes should be concentrated and recycled to antimony production facilities which utilize the electrolytic production process.
Antimony Pentachloride	35	Industrial Disposal	0.005 (as Sb)	0.05 (as Sb)	XII	When dissolved in water and neutralized, the slightly soluble oxide is formed. Removal of the oxide is followed by sulfide precipitation to ensure the removal of the metal ion from solution. The antimony oxides can be sent to a refiner or placed in long term storage.
Antimony Pentafluoride	36	National Disposal Site	.005 (as Sb)	.05 (as Sb)	VIII	The compound is dissolved in dilute HCl and saturated with H_2S. The precipitate (antimony sulfide) is filtered, washed, and dried. The filtrate is air stripped of dissolved H_2S and passed into an incineration device equipped with a lime scrubber. The stripped filtrate is reacted with excess lime, the precipitate (CaF_2 - $CaCl_2$ mixture) is disposed of by land burial. (This is a proposed process).
Antimony Pentasulfide	37	Industrial Disposal	0.005 as Sb	0.05 as Sb	XII	Landfill in California Class 1 type sites.
Antimony Potassium Tartrate	38	Industrial Disposal	0.005 as Sb	0.05 as Sb	XII	Dissolve wastes in water, acidify and precipitate the sulfide using hydrogen sulfide as the reactant. The antimony sulfide precipitate should be returned to suppliers or manufacturers for reprocessing or be placed into long term storage.
Antimony Sulfate	39	Industrial Disposal	0.005 as Sb	0.05 as Sb	XII	Landfill in California Class 1 type sites.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Antimony Trichloride	41	Industrial Disposal	0.005 (as Sb)	0.05 (as Sb)	XII	When dissolved in water and neutralized, the slightly soluble oxide is formed. Removal of the oxide is followed by sulfide precipitation to ensure the removal of the metal ion from solution. The antimony oxides can be sent to a refiner or placed in long term storage.
Antimony Trifluoride	43	National Disposal Site	.005 (as Sb)	.05 (as Sb)	VIII	The compound is dissolved in dilute HCl and saturated with H_2S. The precipitate (antimony sulfide) is filtered, washed, and dried. The filtrate is air stripped of dissolved H_2S and passed into an incineration device equipped with a lime scrubber. The stripped filtrate is reacted with excess lime, the precipitate (CaF_2-$CaCl_2$ mixture) is disposed of by land burial. (This is a proposed process.)
Antimony Trioxide	45	Industrial Disposal	0.005 as Sb	0.05 as Sb	XII	Wastes should be concentrated and recycled to antimony production facilities which utilize the electrolytic production process.
Antimony Trisulfide	40	Industrial Disposal	0.005 as Sb	0.05 as Sb	XII	Landfill in California Class 1 type sites.
Arsenic	46	Industrial Disposal	0.005	0.05	XII	Elemental arsenic wastes should be placed in long term storage or returned to suppliers or manufacturers for reprocessing.
Arsenic Pentaselenide	467	Industrial Disposal	0.005 as As	0.05 as As	XII	Wastes should be placed in long term storage or returned to suppliers or manufacturers for reprocessing.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Arsenic Trichloride	50	National Disposal Site	0.005 as As	0.05 as As	XII	Hydrolyze to arsenic trioxide utilizing scrubbers for hydrogen chloride abatement. The trioxide may then be placed in long term storage.
Arsenic Trioxide	51	National Disposal Site	.005 (as As)	.05 (as As)	VI	Long term storage in large siftproof and weatherproof silos.
Asbestos	468	Municipal Type Disposal	0.05 fibers per ml greater than 5 in length	500	XII	Landfill in a California Class 2 type facility.
Barium Carbonate	52	Industrial Disposal	0.005	1.0	XII	Chemical precipitation usually utilizing sulfuric acid to form barium sulfate which may be separated from the stream and recycled. The supernatant may then be neutralized and discharged into the sewer system.
Barium Chloride	53	Industrial Disposal	0.005	1.0	XII	Chemical reaction with water, caustic soda and slaked lime, resulting in precipitation of the metal sludge which may be landfilled. The supernatant liquid may be neutralized with acid and discharged into the sewer system.
Barium Cyanide	469	Industrial Disposal	0.005	0.01 as CN	XII	Chemical precipitation of barium sulfate following oxidation of the cyanide with chlorine. The reactant in the precipitation reaction is generally sulfuric acid. The sulfate may be recovered for recycle and the supernatant may be discharged into the sewer after neutralization.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Barium Fluoride	470	Industrial Disposal	.005 (as Ba)	1.0 (as Ba)	XII	Precipitation with soda ash or slaked lime - resulting sludge should be sent to a California Class 1 type landfill. The supernatant liquid is neutralized with sulfuric acid to form the insoluble barium sulfate.
Barium Nitrate	471	Industrial Disposal	0.005	1.0	XII	Chemical reaction with water, caustic soda and slaked lime, resulting in precipitation of the metal sludge which may be landfilled. The supernatant liquid may be neutralized with acid and discharged into the sewer system.
Barium Sulfide	472	Industrial Disposal	0.005	1.0	XII	Chemical reaction with water, caustic soda and slaked lime, resulting in precipitation of the metal sludge which may be landfilled. The supernatant liquid may be neutralized with acid and discharged into the sewer system.
Benzene	54	Municipal Type Disposal	0.80	3.5	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewer after preliminary treatment; incineration (for dilute organic mixture).
Benzene Hexachloride (Lindane)	55	National Disposal Site	.005	.025	V	Concentrated: Incineration (1,500F, 0.5 seconds minimum for primary combustion; 2,200F, 1.0 second for secondary combustion) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated-carbon beds; alkaline hydrolysis.
Benzene Sulfonic Acid	56	Industrial Disposal	0.05	0.25	X	Concentrated: Incineration followed by scrubbing to remove the SO_2 gas. Dilute: Biological or chemical degradation using conventional waste water techniques; treatment with lime to precipitate out calcium benzene sulfonate which can be landfilled in a California Class 1 type site.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Benzoic Acid	57	Municipal Type Disposal	0.25	1.25	X	Concentrated: Incineration. Dilute: Biodegradation with unacclimated activated sludges in municipal sewage treatment plants.
Benzoyl Peroxide	514	Industrial Disposal	0.05	0.45	XI	Decomposition with sodium hydroxide. The final solution of sodium benzoate, which is very biodegradable, may be flushed into the drain. Disposal of large quantities of solution may require pH adjustment before release into the sewer; controlled incineration after mixing with a noncombustible material.
Benzyl Chloride	58	Industrial Disposal	.05	0.25	X	Concentrated: Incineration (1500F, 0.5 seconds minimum for primary combustion; 2200F, 1.0 second for secondary combustion). Elemental chlorine formation may be alleviated through injection of steam or methane into the combustion process. Dilute aqueous waste: Convert to the alcohol with caustic, then subject to secondary treatment with activated sludge. Dilute organic waste: incineration followed by scrubbing to remove HCl.
Beryllium Carbonate	473	Industrial Disposal	0.0001 as Be	1.0 as Be	XII	Wastes should be converted into the chemically inert oxide using incineration and particulate collection techniques. The oxides may be landfilled.
Beryllium Chloride	474	Industrial Disposal	0.0001 as Be	1.0 as Be	XII	Wastes should be converted into chemically inert oxide using incineration and particulate collection techniques. The oxides may be landfilled.
Beryllium Hydroxide	475	Industrial Disposal	0.0001 as Be	1.0 as Be	XII	Wastes should be converted into chemically inert oxide using incineration and particulate collection techniques. The oxides may be landfilled.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Beryllium Oxide	476	Industrial Disposal	0.0001 as Be	1.0 as Be	XII	Wastes should be converted into chemically inert oxide using incineration and particulate collection techniques. The oxides may be landfilled.
Beryllium, Powder	59	Industrial Disposal	0.0001 as Be	1.0 as Be	XII	Wastes should be converted into the chemically inert oxide using incineration and particulate collection techniques. The oxides may be landfilled.
Beryllium Selenate	477	Industrial Disposal	0.0001 as Be	1.0 as Be	XII	Wastes should be converted into chemically inert oxide using incineration and particulate collection techniques. The oxides may be landfilled.
Borox, Dehydrated	381	Municipal Type Disposal	0.02	0.10	XII	The material is diluted to the recommended provisional limit in water. The pH is adjusted to between 6.5 and 9.1 and then the material can be discharged into sewers or natural streams.
Boric Acid	60	Industrial Disposal	0.1	1.0 as B	XII	Chemical reaction with lime to form calcium borates which may be filtered from solution. The liquid must be further treated with adsorptive clays or ion exchange. The sludges and clays may be deposited in California Class 1 type landfills and the liquid may be neutralized and discharged into the sewer system.
Boron Chloride	62	Industrial Disposal	0.03	0.15	XII	Addition of soda ash-slaked lime solution to form the corresponding sodium and calcium salt solution. This solution can be safely discharged after dilution.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Boron Hydrides	61,505	National Disposal Site	Diborane .001 Pentaborane .0001 Decaborane .003	Diborane .005 Pentaborane .0005 Decaborane .015	VII	Incineration with aqueous scrubbing of exhaust gases to remove B_2O_3 particulates. Hydrolysis with subsequent evaporation to solid boric acid (Generally not applicable to borone containing solid wastes)
Boron Trifluoride	63	Industrial Disposal	0.03	0.15	XII	Chemical reaction with water to for boric acid and fluorboric acid. The fluorboric acid is reacted with limestone forming boric acid and calcium fluoride. The boric acid may be discharged into the sewer system while the calcium fluoride may be recovered or landfilled.
Bromic Acid	64	Industrial Disposal	0.007 as Br	0.035 as Br	XII	Chemical reaction with iron turnings forming ferrosoferric bromide. This is then decomposed by sodium carbonate forming carbon dioxide and sodium bromide which may be crystallized and recovered.
Bromine	65	Industrial Disposal	0.007	0.035	XII	Aqueous streams containing bromine may be air stripped of the bromine which is easily condensed in ice cooled condensers. The liquid bromine is generally recycled.
Bromine Pentafluoride	66	National Disposal Site	.007	Reacts quantitatively with water	VII	Chemical conversion to carbon tetrafluoride and bromine in a charcoal reactor. The carbon tetrafluoride is vented and the bromine is collected in an ice water cooled trap.
Butadiene	68	Municipal Type Disposal	22	110	X	Concentrated: Incineration Dilute: Discharge of dilute aqueous solutions into municipal sewers after preliminary treatment. Incineration (for dilute organic mixture).

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Butane	69	Municipal Type Disposal	12	60	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture).
1,2,4-Butanetriol Trinitrate	515	Industrial Disposal	0.02	0.1	XI	The current method of absorption in sawdust, wood pulp or fullers earth followed by open pit burning is feasible but unsatisfactory because of the NO_x evolved. Methods currently under investigation for minimum environmental impact include bacterial degradation and controlled incineration with after burners and scrubbers for abatement of NO_x.
Butanols (Butyl Alcohol-n, -iso, -sec, -teyl)	70,74, 498	Municipal Type Disposal	3.0	15	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
1-Butene	71	Municipal Type Disposal	22	110	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture).
Butyl Acetate	72	Municipal Type Disposal	7.1	35.5	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Butyl Acrylate	73	Municipal Type Disposal	1.0	5.0	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
n-Butylamine	75	Municipal Type Disposal	0.15	0.75	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Butylene	76	Municipal Type Disposal	22	110	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture).
Butyl Mercaptan	77	Industrial Disposal	0.01	0.05	X	Concentrated: Incineration followed by effective scrubbing of the effluent gas. Dilute Waste: Incineration (2000 F) followed by scrubbing with a caustic solution.
Butyl Phenol	78	Municipal Type Disposal	0.19	0.001	X	Concentrated: Controlled incineration. Dilute: Biological treatment with activated sludges via municipal waste treatment plants.
Butyraldehyde	79	Municipal Type Disposal	0.1	0.5	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Cacodylic Acid	80	National Disposal Site	.005	.05	VI	Long-term storage in concrete vaults or weatherproof bins; Landfill in a California "Class 1" site for small amounts.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Cadmium	81	National Disposal Site	.002	.01	VI	Concentrated: Coagulation with lime, then sedimentation followed by sand filtration. The effluent from this process should be treated further using activated-carbon beds or ion exchange. Dilute: Absorption with activated-carbon beds; coagulation with time followed by filtration.
Cadmium Chloride	83	National Disposal Site	.002	.01	VI	Concentrated: Coagulation with lime, then sedimentation followed by sand filtration. The effluent from this process should be treated further using activated-carbon beds or ion exchange. Dilute: Adsorption with activated-carbon beds; coagulation with lime followed by filtration.
Cadmium Cyanide	84	National Disposal Site	.002 (as Cd)	.01 (as CN)	V	Concentrated: Chlorination under alkaline conditions (after the waste is diluted). Additional treatment to remove the cadmium ion. Dilute: Oxidation by the hypochlorite ion (chlorination under alkaline conditions).
Cadmium Fluoride	478	National Disposal Site	.002 (as Cd)	.01 (as Cd)	XII	Precipitation with soda ash on slaked lime - resulting sludge should be sent to a California Class 1 type landfill. The supernatant is treated further with ion exchange, reverse osmosis, or activated carbon adsorption.
Cadmium Nitrate	479	National Disposal Site	.002	.01	VI	Concentrated: Coagulation with lime, then sedimentation followed by sand filtration. The effluent from this process should be treated further using activated-carbon beds or ion exchange. Dilute: Adsorption with activated-carbon beds; Coagulation with lime followed by filtration.
Cadmium Oxide	85	National Disposal Site	.001	.01	VI	Concentrated: Coagulation with lime, then sedimentation followed by sand filtration. The effluent from this process should be treated further using activated-carbon beds or ion exchange. Dilute: Adsorption with activated-carbon beds; coagulation with lime followed by filtration. Fume: Electrostatic precipitators, bag houses, and cyclones.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Cadmium Phosphate	86	National Disposal Site	.002	.01	VI	Concentrated: Coagulation with lime, then sedimentation followed by sand filtration. The effluent from this process should be treated further using activated-carbon beds or ion exchange. Dilute: Adsorption with activated-carbon beds; coagulation with lime followed by filtration.
Cadmium Potassium Cyanide	480	National Disposal Site	.002	.01	VI	Concentrated: Coagulation with lime, then sedimentation followed by sand filtration. The effluent from this process should be treated further using activated-carbon beds or ion exchange. Dilute: Adsorption with activated-carbon beds; coagulation with lime followed by filtration. Further treatment to remove the cyanide ion.
Cadmium, Powered	82	National Disposal Site	.002	.01	VI	Concentrated Aqueous Solution: Coagulation with lime, then sedimentation followed by sand filtration. The effluent from this process should be treated further using activated-carbon beds or ion exchange. Dilute Aqueous Solution: Adsorption with activated-carbon beds; coagulation with lime followed by filtration. Removal from air: Electrostatic precipitators, bag houses, and cyclones.
Cadmium Sulfate	481	National Disposal Site	.002	.01	VI	Concentrated: Coagulation with lime, then sedimentation followed by sand filtration. The effluent from this process should be treated further using activated-carbon beds or ion exchange. Dilute: Adsorption with activated-carbon beds; coagulation with lime followed by filtration.
Calcium Arsenate	87	National Disposal Site	.005 (as As)	.05 (as As)	VI	Long term storage in large, weatherproof, and siftproof storage bins or silos; Landfill in a California Class 1 site.
Calcium Arsenite	88	National Disposal Site	.005 (as As)	.05 (as As)	VI	Long term storage in large weatherproof and siftproof storage bins or silos; Landfill in a California Class 1 site.
Calcium Carbide	89	Industrial Disposal	0.025	0.125	XII	The waste material is slowly added to a large container of water. The acetylene gas liberated is burned off with a pilot flame. The remaining residue is lime and can be sent to a landfill.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Calcium Chloride	90	Municipal Type Disposal	0.07 (as HCl)	250 (as Cl)	XII	Precipitation with soda ash to yield the insoluble calcium carbonate. The remaining brine solution, when its sodium chloride concentration is below 250 mg/l, may be discharged into sewers and waterways.
Calcium Cyanide	91	National Disposal Site	.05 (as CN)	.01 (as CN)	V	Concentrated: Chlorination under alkaline conditions (after the waste is diluted). Dilute: Oxidation by the hypochlorite ion (chlorination under alkaline conditions).
Calcium Fluoride	92	Industrial Disposal	0.025 as F	0.6 to 1.7 as F	XII	Landfill in California Class 2 type sites.
Calcium Hydride	93	Industrial Disposal	0.025	0.125	XII	The waste material is mixed with dry sand before adding to water. The hydrogen gas liberated is burned off with a pilot flame. The remaining residue is a hydroxide and should be neutralized by an acid before being disposed of.
Calcium Hydroxide	94	Municipal Type Disposal	0.05	0.25	XII	Neutralization with hydrochloric acid to yield calcium chloride. The calcium chloride formed can be treated by the method described earlier for this compound.
Calcium Hypochlorite	482	Industrial Disposal	0.025	0.125	XII	Dissolve the material in water and add to a large volume of concentrated reducing agent solution, then acidify the mixture with H_2SO_4. When reduction is complete, soda ash is added to make the solution alkaline. The alkaline liquid is decanted from any sludge produced, neutralized, and diluted before discharge to a sewer or stream. The sludge is landfilled.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Calcium Oxide	483	Municipal Type Disposal	0.05	0.25	XII	Neutralization with hydrochloric acid to yield calcium chloride. The calcium chloride formed can be treated by the method described earlier for this compound.
Calcium Phosphate	95	Municipal Type Disposal	0.01	0.05	XII	Landfill in a California Class 2 type facility.
Camphor	96	Municipal Type Disposal	0.12	0.6	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Carbolic Acids (Phenol)	97 327	Municipal Type Disposal	0.19	0.001	X	Concentrated: Controlled incineration. Dilute: Biological treatment with activated sludges via municipal waste treatment plants.
Carbon Disulfide	98	Industrial Disposal	*0.2 ppm	1.0	X	Controlled incineration - a sulfur dioxide scrubber is necessary when combusting significant quantities of carbon disulfide.
Carbon Monoxide	99	Industrial Disposal	0.055	2.75	XII	Controlled incineration.

*Note that units are ppm not mg/M^3.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Carbon Tetrachloride	100	Industrial Disposal	0.65	1.95	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Chloral Hydrate	104	Industrial Disposal	0.002	0.01	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Chlorates with Red Phosphorus	516	Industrial Disposal	0.001	0.005	XIII	Controlled incineration followed by effluent scrubbers to abate NOx, P_4O_{10}, HCl, SO_2 and metal oxides.
Chlorobenzene	108, 278	Industrial Disposal	3.5	17.5	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Chlordane	484	National Disposal Site	.005	.025	V	Concentrated: Incineration (1500F, 0.5 seconds minimum for primary combustion; 3200F, 1.0 second for secondary combustion) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated-carbon beds.
Chlorine	105	National Disposal Site	.03	0.15	VIII	Water scrubbing and stripping units are used to remove chlorine from a gas stream. Alkaline scrubbers are used to remove the residual chlorine from the water scrubber vent gas.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Chlorine Trifluoride and Chlorine Pentafluoride	106	National Disposal Site	For ClF_3 .001 ppm For ClF_5 .001 ppm	Reacts quantitatively with water to form Cl_2 15 HCl .35 HF .02	VII	Reaction with a charcoal bed to form carbon tetrafluoride and chlorine. The carbon tetrafluoride is vented and the chlorine produced is removed by a caustic scrubber.
Chloroform (Trichloromethane)	109	Industrial Disposal	1.2	6	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Chloropicrin	111	Industrial Disposal	.007	.035	XI	Concentrated: Incineration (1500F, 0.5 seconds minimum for primary combustion; 2200F, 1.0 second for secondary combustion) after mixing with other fuel. The formation of elemental chlorine may be prevented by injection of steam or using methane as a fuel in the process. Dilute waste: Incineration with scrubbing for HCl and NO_x removal.
Chlorosulfonic Acid	112	Industrial Waste	0.05 units are ppm, not mg/M^3	0.05	XII	Chemical decomposition using sodium bicarbonate, and ammonium hydroxide as reactants with dilution with water, neutralization and discharge into the sewer system.
Chrome	113	Industrial Disposal	0.01	None available	XII	Recycling scrap for reuse.
Chromic Acid (Liquids, Chromium Trioxide)	114	National Disposal Site	.001	.05	VI	Concentrated: Reduction to Cr III and precipitation by pH adjustment. Precipitates are normally land filled in a California "Class 1" site. Dilute: Adsorption on activated carbon; Ion exchange.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/1)		
Chromic Fluoride	485	Industrial Disposal	0.005 as Cr	0.05 as Cr	XIII	Alkaline precipitation of the heavy metal gel followed by effluent neutralization and discharge into the sewer system. The heavy metal may be recovered from the sludge or the sludge may be landfilled in a California Class 1 type site.
Chromic Sulfate	486	Industrial Disposal	0.005 as Cr	0.05 as Cr	XIII	Alkaline precipitation of the heavy metal gel followed by effluent neutralization and discharge into the sewer system. The heavy metal may be recovered from the sludge or the sludge may be landfilled in a California Class 1 type site.
Chromium Cyanide	487	Not Applicable	0.005 as Cr	0.01 as CN	XIII	Does not exist and therefore treatment methods are not applicable.
Coal	488	Municipal Type Disposal	0.02	500	XII	Landfill in a California Class 2 type facility.
Cobalt Chloride	489	Industrial Disposal	0.001 as Co	0.05 as Co	XII	Chemical reaction with water, caustic soda and slaked lime, resulting in precipitation of the metal sludge which may be landfilled. The supernatant liquid may be neutralized with acid and discharged into the sewer system.
Cobalt Nitrate	116	Industrial Disposal	0.001 as Co	0.05 as Co	XII	Chemical precipitation usually utilizing sulfuric acid to form barium sulfate which may be separated from the stream and recycled. The supernatant may then be neutralized and discharged into the sewer system.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Copper Acetoarsenite	490	National Disposal Site	.005 (as As)	.05 (as As)	VI	Long term storage in large weatherproof and siftproof storage bins or silos; landfill in a California Class I site.
Copper Acetylide	517	National Disposal Site	.01 (as Cu)	1.0 as Cu	VII	Detonation (on an interim basis until a fully satisfactory techniqur is developed) - the copper salts liberated are disposed of in a California Class 1 landfill site.
Copper Arsenates	119	National Disposal Site	.005 (as As)	.05 (as As)	VI	Long term storage in large, weatherproof, and siftproof storage bins or silos; landfill in a California Class 1 site.
Copper Chlorotetrazole	518	National Disposal Site	.01 (as Cu)	1.0 (as Cu)	VII	Controlled combustion employing a rotary kilm incinerator equipped with appropriate scrubbing devices. The explosive is fed to the incinerator as a slurry in water. The scrubber effluent would require treatment for recovery of particulate metal compounds formed as combustion products.
Copper Cyanides	120	National Disposal Site	.01 (as Cu)	.01 (as Cu)	V	Concentrated: Chlorination under alkaline conditions (after the waste is diluted). Dilute: Oxidation by the hypochlorite ion (chlorination under alkaline conditions).
Copper Nitrate	121	Industrial Disposal	0.01 as Cu	1.0 as Cu	XII	Copper wastes can be concentrated through the use of ion exchange, reverse osmosis or multiple effect evaporators to the point where copper can be electrolytically removed and sent to a reclaiming firm. If recovery is not desired, the copper can be precipitated through the use of caustics and the sludges may be landfilled in a California Class 1 type facility. Dilute wastes may be discharged into sewer systems after neutralization.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Copper Sulfate	122	Industrial Disposal	0.01 as Cu	1.0 as Cu	XII	Copper wastes can be concentrated through the use of ion exchange, reverse osmosis, or multiple effect evaporators to the point where copper can be electrolytically removed and sent to a reclaiming firm. If recovery is not desired, the copper can be precipitated through the use of caustics and the sludges may be landfilled in a California Class 1 type facility. Dilute wastes may be discharged into sewer systems after neutralization.
Creosote (coal tar)	123	Municipal Type Disposal	0.22	.001	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solution into the municipal sewer after preliminary treatment; incineration (for dilute organic mixture).
Cresol (Cresylic Acid)	124, 125	Municipal Type Disposal	0.19	0.001	X	Concentrated: Controlled incineration. Dilute: Biological treatment with activated sludges via municipal waste treatment plants.
Crotonaldehyde	126	Municipal Type Disposal	0.06	0.30	X	Concentrated: Contolled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Cumene	127	Municipal Type Disposal	2.45	12.25	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture).
Cuprous (Copper) Cyanide	128	National Disposal Site	.01 (as Cu)	.01 (as CN)	V	Concentrated: Chlorination under alkaline conditions (after the waste is diluted). Dilute: Oxidation by the hypochlorite ion (chlorination under alkaline conditions).

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Cyanides	129	National Disposal Site	.05 (as CN)	.01 (as CN)	V	Oxidation by the hypochlorite ion (chlorination under alkaline conditions) for both dilute and concentrated wastes. Concentrated wastes should be diluted before chlorination.
Cyanoacetic Acid	130	Industrial Disposal	0.01	0.05	X	Concentrated: Controlled incineration (oxides of nitrogen are removed from the effluent gas by scrubber, and/or thermal devices). Dilute: Biological treatment (highly dependent upon pH and temperature conditions); activated carbon treatment (as a polishing step to be used in conjunction with biological treatment).
Cyanuric Triazide	519	Industrial Disposal	Not Available	Not Available	XI	Bags containing the explosive, wet with water, are carried to a destruction pit, placed in intimate contact with each other and a blasting cap placed between bags to initiate the explosives. This should be done by an ordnance disposal team experienced in handling initiating explosives.
Cyclohexane	131	Municipal Type Disposal	10.5	52.5	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture)
Cyclohexanol	132	Municipal Type Disposal	2.0	10	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Cyclohexanone	133	Municipal Type Disposal	2.0	10.0	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Cyclohexylamine	134	Municipal Type Disposal	0.1	0.5	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
DDD	136	National Disposal Site	.01	.05	V	Concentrated: Incineration (1,500 F, 0.5 seconds minimum for primary combustion; 2,200 F, 1.0 second for secondary combustion) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated-carbon beds; alkaline hydrolysis.
DDT	137	National Disposal Site	.01	.05	V	Concentrated: Incineration (1,500 F, 0.5 seconds minimum for primary combustion; 2,200 F, 1.0 second for secondary combustion) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated-carbon beds; alkaline hydrolysis.
Decyl Alcohol	138	Municipal Type Disposal	1.0	5	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Demeton	491	National Disposal Site	.001	.005	V	Concentrated: Incineration (1,500 F, 0.5 seconds minimum for primary combustion; 2,200 F, 1.0 second for secondary combustion) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated-carbon beds; primary waste treatment followed by an activated sludge process.
Detonators	520	National Disposal Site	Not Available	Not Available	VII	The Chemical Agent Munition Disposal System under development by the U.S. Army Materiel Command.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Di-n-Butyl Phthalate	139	Municipal Type Disposal	0.05	0.25	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Diazodinitrophenol	521	National Disposal Site	Not Available	Not Available	VII	Controlled incineration - the incinerator is equipped with suitable afterburner or alkaline scrubbing systems for the abatement of the NOx liberated. Military and commercial munitions should be disposed of by the U.S. Army Materiel Command's Deactivation Furnace.
O-Dichlorobenzene	140,278	Industrial Disposal	3.0	15.0	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
P-Dichlorobenzene	141	Industrial Disposal	4.5	22.5	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Dichlorofluoromethane (Freon)	142	Industrial Disposal	49.5	247.5	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Dichloroethyl Ether	143	Industrial Disposal	0.30	1.5	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Dichloromethane (Methylene Chloride)	144	Industrial Disposal	17.4	87	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
2,4-D (Dichlorophenoxyacetic Acid)	135	National Disposal Site	0.1	0.5	V	Concentrated: Incineration (1500 F, 0.5 seconds minimum for primary combustion; 2200 F, 1.0 second for secondary combustion) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated carbon beds; Ion Exchange after neutralization to the sodium salt.
1,2 - Dichloropropane	145, 363	Industrial Disposal	3.5	17.5	X	Incineration--preferably after mixing with another combustible fuel. Care must exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
1,3 - Dichloropropene (Propylene Dichloride)	146, 363	Industrial Disposal	0.03	0.15	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Dichlorotetrafluoroethane	147	Industrial Disposal	70	350	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Dicylopentadiene	148	Municipal Type Disposal	15	75	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture).

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Dieldrin	149	National Disposal Site	.0025	.012	V	Concentrated: Incineration (1,500 F, 0.5 seconds minimum for primary combustion; 3,200 F, 1.0 second for secondary combustion) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated-carbon beds.
Diethanolamine	150	Municipal Type Disposal	0.06	0.30	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Diethylamine	151	Municipal Type Disposal	0.75	3.75	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Diethylether	152	Industrial Disposal	12	60	XI	Concentrated waste containing no peroxides: Discharge liquid at a controlled rate near a pilot flame. Concentrated waste containing peroxides: Perforation of a container of the waste from a safe distance followed by open burning. Dilute Waste: Incineration (1500 F minimum).
Diethylstilbestrol	492	Municipal Type Disposal	0.19	0.001	X	Concentrated: Controlled incineration. Dilute: Biological treatment with activated sludges via municipal waste treatment plants.
Diethylene Glycol	154	Municipal Type Disposal	2.0	10	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Diethyl Trimine	155	Municipal Type Disposal	0.04	0.20	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Diisobutylene	156	Municipal Type Disposal	10	50	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture)
Diisobutyl Ketone	157	Municipal Type Disposal	1.5	7.5	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Diisopropanolamine	158	Municipal Type Disposal	0.06	0.30	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Dimethylamine	159	Municipal Type Disposal	0.18	0.90	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Dimethyl Sulfate (Methyl Sulfate)	160	National Disposal Site	0.05	0.25	VIII	Incineration (1800 F, 1.5 seconds minimum) of dilute, neutralized dimethyl sulfate waste is recommended. The incinerator must be equipped with efficient oxides of sulfur scrubbing devices.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M³)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
2,4 - Dinitroaniline	161	Industrial Disposal	0.06	0.30	X	Concentrated: Controlled incineration whereby oxides of nitrogen are removed from the effluent gas by scrubber, catalytic or thermal device. Dilute: Oxidation by activated sludge; adsorption on activated carbon.
Dinitrobenzol (dinitrobenzene)	163	Industrial Disposal	0.01	0.05	XI	Concentrated and dilute waste: Incineration (1800 F, 2.0 seconds minimum) followed by removal of the oxides of nitrogen that are formed using scrubbers and/or catalytic or thermal devices. The dilute wastes should be concentrated before incineration.
Dinitro Cresols	162	National Disposal Site	.002	.01	V	Concentrated: Incineration (600 C minimum) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with granular activated-carbon beds or adsorption with powdered activated carbon.
Dinitrophenol	164	Industrial Disposal	0.002	0.010	XI	Concentrated: Incinerated (1800 F, 2.0 seconds minimum) with adequate scrubbing equipment for the removal of NOx. Dilute: Concentration followed by incineration.
Dinitrotoluene	165	National Disposal Site	.015	1.5	VII	Mixture of the dinitrotoluene contaminated waste with $NaHCO_3$ and solid combustibles followed by incineration in an alkaline-scrubber equipped incinerator unit.
Dioxane (Diethylene Oxide)	153	Industrial Disposal	3.6	18	XI	Concentrated waste containing no peroxides: Discharge liquid at a controlled rate near a pilot flame. Concentrated waste containing peroxides: Perforation of a container of the waste from a safe distance followed by open burning. Dilute Waste: Incineration (1500 F minimum).

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Dipentaerythritol Hexanitrate (DPEHN)	522	National Disposal Site	.02	0.1	VII	Controlled incineration in rotary kiln incinerators equipped with after-burner or flue gas scrubbers. Obsolete military and sporting ammunition containing this material should be destroyed using the Chemical Agent Munition Disposal System.
Diphenylamine (Phenylaniline)	167	Municipal Type Disposal	0.1	0.5	XI	Concentrated: Controlled incineration with adequate scrubbing for NOx removal; landfill in a California Class 1 site. Dilute: Incineration or landfill in a California Class 1 site.
Dipropylene Glycol	168	Municipal Type Disposal	2.0	10	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Dodecyl Benzene	169	Municipal Type Disposal	3.75	18.75	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solution into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture)
Endrin	170	National Disposal Site	.001	.005	V	Concentrated: Incineration (1,500 F, 0.5 seconds minimum for primary combustion; 3,200 F, 1.0 second for secondary combustion) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated-carbon beds.
Epichlorohydrin	171	Industrial Disposal	0.19	0.95	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Ethane	493	Municipal Type Disposal	9	45	X	Concentrated: Incineration Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture)
Ethanol	172	Municipal Type Disposal	19	95	X	Concentrated: Controlled incineration Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Ethanolamine (Monoethanolamine)	173, 279	Municipal Type Disposal	.06	0.30	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Ethyl Acetate	175	Municipal Type Disposal	14	70.0	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Ethyl Acrylate	176	Municipal Type Disposal	1.0	5.0	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Ethylamine	178	Municipal Type Disposal	0.18	0.90	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Ethylbenzene	179	Municipal Type Disposal	4.35	21.75	X	Concentrated: Incineration Dilute: Discharge of dilute aqueous solution into the municipal sewers after preliminary treatment; incineration (for dilute organic mixture).
Ethyl Chloride	180	Industrial Disposal	26	130	X	Incineration - preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formulation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Ethylene	181	Municipal Type Disposal	22	110	X	Concentrated: Incineration Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; incineration (for dilute organic mixture).
Ethylene Bromide (Ethylene Dibromide)	182, 494	Industrial Disposal	1.45	7.25	XI	Concentrated: Controlled incineration with adequate scrubbing and ash disposal facilities. Dilute: Steam stripping - the waste gases from stripping must be burned in incinerators equipped with adequate scrubbing equipment. Removal from air: Refrigerated condensation.
Ethylene Cyanohydrin	183	Industrial Disposal	0.45	1.99	X	Concentrated: Controlled incineration (oxides of nitrogen are removed from the effluent gas by scrubbers and/or thermal devices). Dilute: Biological treatment (highly dependent upon pH and temperature conditions); activated carbon treatment (as a polishing step to be used in conjunction with biological treatment).
Ethylene Diamine	184	Municipal Type Disposal	0.25	1.27	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Ethylene Dichloride	185	Industrial Disposal	2.0	10	X	Incineration - preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Ethylene Glycol	186, 206	Municipal Type Disposal	2.0	1.0	X	Concentrated: Controlled incineration Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Ethylene Glycol Monoethyl Ether	187	Industrial Disposal	2.0	10	XI	Concentrated waste containing no peroxides: Discharge liquid at a controlled rate near a pilot flame. Concentrated waste containing peroxides: Perforation of a container of the waste from a safe distance followed by open burning. Dilute Waste: Incineration (1500 F minimum).
Ethylene Glycol Monoethyl Ether Acetate	188	Industrial Disposal	1.2	6.0	XI	Concentrated waste containing no peroxides: Discharge liquid at a controlled rate near a pilot flame. Concentrated waste containing peroxides: Perforation of a container of the waste from a safe distance followed by open burning. Dilute Waste: Incineration (1500 F minimum).
Ethylenimine	190	Industrial Disposal	0.01	0.05	XI	Concentrated: Mix with acidic water in an acid scrubber. The exit scrubber solution should be sent to a covered holding pond or tank. Solution should be maintained at or below pH4 until analysis indicates polymerization is complete - followed by secondary treatment. Dilute: Controlled incineration followed by scrubbing for removal of NO_x
Ethyl Mercaptan	192	Industrial Disposal	0.01	0.05	X	Concentrated: Incineration followed by effective scrubbing of the effluent gas. Dilute Waste: Incineration (2000 F) followed by scrubbing with a caustic solution.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Ethyl Methyl Ketone	193	Municipal Type Disposal	5.9	29.5	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Ethyl Phthalate	194	Municipal Type Disposal	0.05	0.25	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Ethyl Phenol	196	Municipal Type Disposal	0.19	0.001	X	Concentrated: Controlled incineration. Dilute: Biological treatment with activated sludges via municipal waste treatment plants.
Fatty Acids	197	Municipal Type Disposal	0.25	1.25	X	Concentrated: Incineration. Dilute: Biodegradation with unacclimated activated sludges in municipal sewage treatment plants.
Ferrous Sulfate	198	Industrial Disposal	0.01 as Fe	0.03 as Fe	XI	Chemical precipitation usually utilizing sulfuric acid to form barium sulfate which may be separated from the stream and recycled. The supernatant may then be neutralized and discharged into the sewer system.
Fluorine	200	National Disposal Site	*.001 ppm	.10 ppm (as HF which is a product of the F/H_2O reaction)	VIII	Reaction with a charcoal bed. The product of the reaction is carbon tetrafluoride which is usually vented. Residual fluorine can be combusted by means of a fluorine-hydrocarbon - air burner followed by a caustic scrubber and stack.

---

*Note units are ppm, not mg/M^3

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Formaldehyde	201	Municipal Type Disposal	0.06	0.15	X	Concentrated: Controlled incineration. Dilute: Chemical or biological degradation via municipal waste treatment systems.
Formic Acid	202	Municipal Type Disposal	0.09	0.45	X	Concentrated: Incineration. Dilute: Biodegradation with unacclimated activated sludges in municipal treatment plants.
Furfural	203	Municipal Type Disposal	0.20	1.0	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Furfural Alcohol	204	Municipal Type Disposal	0.20	1.0	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
GB (Non persistent Nerve Gas)	287	National Disposal Site	3×10^{-6}	Not Available	VII	Concentrated: Incineration followed by adequate gas scrubbing equipment; chemical reaction with sodium hydroxide. Dilute: Hydrolysis using caustic soda to accelerate the hydrolysis reactions.
Gelatinized Nitrocellulose (PNC)	523	National Disposal Site	Not Available	Not Available	VII	Controlled incineration in rotary kiln incinerators equipped with afterburners or flue gas scrubbers. Obsolete military munitions containing PNC should be destroyed using the Chemical Agent Munition Disposal System.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Glycerine	205	Municipal Type Disposal	2.0	1.0	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Glycerolmonolacetate Trinitrate (GLTN)	524	Industrial Disposal	0.02	0.1	XI	The current method of absorption in sawdust, wood pulp or fullers earth followed by open pit burning is feasible but unsatisfactory because of the NO_x evolved. Methods currently under investigation for minimum environmental impact include bacterial degradation and controlled incineration with after burners and scrubbers for abatement of NO_x.
Glycol Dinitrate (DDN)	525	National Disposal Site	0.02	0.1	VII	Controlled incineration in the scrubber equipped Deactivation Furnace incinerator (The Chemical Agent Munition Disposal System).
Gold Fulminate	526	National Disposal Site	Not Available	Not Available	VII	Controlled combustion employing a rotary kiln incinerator equipped with appropriate scrubbing devices. The explosive is fed to the incinerator as a slurry in water. The scrubber effluent would require treatment for recovery of particulate metal compounds formed as combustion products.
Guthion	495	National Disposal Site	.002	.01	V	Concentrated: Incineration (1,500 F, 0.5 seconds minimum for primary combustion; 2,200 F, 1.0 second for secondary combustion) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated-carbon beds; primary waste treatment followed by an activated sludge process.
n-Heptane	207	Municipal Type Disposal	20	100	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solution into the municipal sewers after preliminary treatment; incineration (for dilute organic mixture).

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
1-Heptene	208	Municipal Type Disposal	22	110	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solution into the municipal sewer after preliminary treatment; incineration (for dilute organic mixture).
Heptachlor	496	National Disposal Site	.005	.025	V	Concentrated: Incineration (1500 F, 0.5 seconds minimum for primary combustion; 3200 F, 1.0 second for secondary combustion) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated-carbon beds; chemical oxidation with potassium permanganate.
Hexachlorophene	497	Industrial Disposal	Not Available	Not Available	X	Incineration - preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Hexamethylene Diamine	210	Municipal Type Disposal	0.04	0.20	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Hexane	211	Municipal Type Disposal	18	90	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solution into the municipal sewers after preliminary treatment; incineration (for dilute organic mixture).
Hydrazine (Anhydrous Diamine)	212	Industrial Disposal	0.01	1.0	XIII	Controlled incineration with facilities for effluent scrubbing to abate any ammonia formed in the combustion process.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Hydrazine Azide/ Hydrazine	527	Industrial Disposal	.013	.065	XI	Incineration - the blends should be diluted with water and sprayed into an incinerator equipped with a scrubber.
Hydrazoic Acid	528	Industrial Disposal	0.005	0.025	XIII	Chemical decomposition utilizing nitrous acid followed by neutralization and dilution with water and discharge into the sewer system.
Hydrobromic Acid (Hydrogen Bromide)	213	Industrial Disposal	0.03 units are ppm not mg/M^3	0.05	XIII	Concentrated Waste: Separation and purification using fractionation permits recovery of pure hydrogen bromide. Vapors may be collected using refrigerated condensors.
Hydrochloric Acid	214	Industrial Disposal	0.07 mg (vapor)/ M^3	0.35	XII	Soda ash - slaked lime is added to form the neutral solution of chloride of sodium and calcium. This solution can be discharged after dilution with water.
Hydrocyanic Acid (Aq)	215	Industrial Disposal	0.11	0.01 as CN	XIII	Chemical conversion to ammonia and carbon dioxide using chlorine or hypochlorite in a basic media. Controlled incineration is also adequate to totally destroy cyanide.
Hydrofluoric Acid	216	Industrial Disposal	0.02 mg (vapor)/ M^3	0.01	XII	Precipitation with soda ash-slaked lime solution to form the insoluble calcium fluoride which is removed by filtration. The neutral supernatant liquid can be discharged after dilution.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Hydrogen Chloride (G) (Anhydrous)	217	Industrial Disposal	0.07 mg (vapor)/ M^3	0.35	XII	Removal from a gas stream: scrub with water or caustic. Dilute aqueous: Neutralization with soda ash - slaked lime solution.
Hydrogen Cyanide	218	Industrial Disposal	0.11	0.01 as CN	XIII	Chemical conversion to ammonia and carbon dioxide using chlorine or hypochlorite in a basic media. Controlled incineration is also adequate to totally destroy cyanide.
Hydrogen Peroxide (Aq. < 52%)	219	Industrial Disposal	0.014	0.07	XII	Dilution with water to release the oxygen. After decomposition the waste stream may be discharged safely.
Hydrogen Sulfide	221	National Disposal Site	0.1	0.75	XIII	Conversion to elemental sulfur utilizing such processes as the Claus-Bevon or Claus-IFP-Bevon processes.
Hydroquinone	220	Municipal Type Disposal	0.02	0.10	XI	Concentrated: Incineration (1800 F, 2.0 seconds minimum) followed by scrubbing to remove harmful combustion products. Dilute: Conventional secondary sewage treatment methods (activated sludge, aerated lagoons or trickling filters).
Hypochlorite, Sodium	222	Industrial Disposal	0.02	0.10	XII	Dissolve the material in water and add to a large volume of concentrated reducing agent solution, then acidify the mixture with H_2SO_4. When reduction is complete, soda ash is added to make the solution alkaline. The alkaline liquid is decanted from any sludge produced, neutralized, and diluted before discharge to a sewer or stream. The sludge is landfilled.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Iodine, Tincture of	223	Industrial Disposal	0.01	0.05	XII	Iodine is a volatile material and can be easily recovered by fractionation.
Isobutyl Acetate	224	Municipal Type Disposal	7.0	35.0	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Isopentane	225	Municipal Type Disposal	15	75	X	Concentrated: Incineration Dilute: Discharge of dilute aqueous solution into the municipal sewers after preliminary treatment; incineration (for dilute organic mixture).
Isophorane	226	Municipal Type Disposal	0.55	2.75	X	Concentrated: Controlled incineration Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Isoprene	227	Municipal Type Disposal	22	110	X	Concentrated: Incineration Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; incineration (for dilute organic mixture).
Isopropanol	228, 230	Municipal Type Disposal	9.8	49	X	Concentrated: Controlled incineration Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Isopropyl Acetate	229	Municipal Type Disposal	9.5	47.5	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Isopropyl Amine	231	Municipal Type Disposal	0.12	0.60	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Isopropyl Ether	232	Industrial Disposal	10.5	52.5	XI	Concentrated waste containing no peroxides: Discharge liquid at a controlled rate near a pilot flame. Concentrated waste containing peroxides: Perforation of a container of the waste from a safe distance followed by open burning. Dilute waste: Incineration (1500 F minimum).
Lead	233	Industrial Disposal	0.0015	0.05	XIII	Recycle using blast furnaces designed for primary lead processing to convert waste into lead ingots. Small quantities may be landfilled in California Class 1 site.
Lead Acetate	234	Industrial Disposal	0.0015 as Pb	0.05 as Pb	XIII	Concentrated waste: Chemical conversion to the nitrate using nitric acid followed by conversion to the sulfide. The sulfide is then collected and sent through smeltering operations to recover the lead. Dilute wastes: Chemical conversion to the sulfide or carbonate. These precipitates are collected and sent to smelters for lead recovery.
Lead Arsenate	235	National Disposal Site	.005 (as As)	.05 (as As)	VI	Long term storage in large, weatherproof, and siftproof storage bins or silos; landfill in a California Class 1 site.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Lead Arsenite	236	National Disposal Site	.005 (as As)	.05 (as As)	V	Long term storage in large weatherproof and sift proof storage bins or silos; landfill in a California Class I site.
Lead Azide	529	National Disposal Site	.0015 (as Pb)	.05 (as Pb)	VII	Electrolytic Destruction - this process converts the lead azide to metallic lead and nitrogen. Sporting ammunition and obsolete military munitions should be disposed of by The Chemical Agent Munition Disposal System (U.S. Army Materiel Command's Deactivation Furnace).
Lead Carbonate	237	Industrial Disposal	0.0015 as Pb	0.05 as Pb	XIII	Concentrated waste: Chemical conversion to the nitrate using nitric acid followed by conversion to the sulfide. The sulfide is then collected and sent through smeltering operations to recover the lead. Dilute wastes: Chemical conversion to the sulfide or carbonate. These precipitates are collected and sent to smelters for lead recovery.
Lead Chlorite	238	Industrial Disposal	0.0015 as Pb	0.05 as Pb	XIII	Concentrated waste: Chemical conversion to the nitrate using nitric acid followed by conversion to the sulfide. The sulfide is then collected and sent through smeltering operations to recover the lead. Dilute wastes: Chemical conversion to the sulfide or carbonate. These precipitates are collected and sent to smelters for lead recovery.
Lead Cyanide	239	National Disposal Site	.0015 (as Pb)	.01 (as CN)	V	Oxidation by the hypochlorite ion (chlorination under alkaline conditions) for both dilute and concentrated wastes. Concentrated wastes should be diluted before chlorination.
Lead 2,4 Dinitroresorcinate (LDNR)	530	National Disposal Site	.0015 (as Pb)	.05 (as Pb)	VII	Controlled combustion - the lead dinitroresorcinate is fed to the incinerator as slurry in water. The scrubber effluent requires treatment for recovery of the particulate lead oxide formed as a product of combustion; U.S. Army Materiel Command's Deactivation Furnace.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Lead Nitrate	240	Industrial Disposal	0.0015 as Pb	0.05 as Pb	XIII	Concentrated waste: Chemical conversion to the nitrate using nitric acid followed by conversion to the sulfide. The sulfide is then collected and sent through smeltering operations to recover the lead. Dilute wastes: Chemical conversion to the sulfide or carbonate. These precipitates are collected and sent to smelters for lead recovery.
Lead Nitrite	241	Industrial Disposal	0.0015 as Pb	0.05 as Pb	XIII	Concentrated Waste: Chemical conversion to the nitrite using nitric acid followed by conversion to the sulfide. The sulfide is then collected and sent through smeltering operations to recover the lead. Dilute wastes: Chemical conversion to the sulfide or carbonate. These precipitates are collected and sent to smelters for lead recovery.
Lead Oxide	242	Industrial Disposal	0.0015 as Pb	0.05 as Pb	XIII	Chemical conversion to the sulfide or carbonate followed by collection of the precipitate and lead recovery via smelting operations. Landfill of the oxide is also an acceptable procedure.
Lead Styphnate	531	National Disposal Site	.0015 (as Pb)	.05 (as Pb)	VII	Controlled incineration - the lead styphnate is fed to the incinerator as a slurry in water. The scrubber effluent would then require treatment for recovery of the particulate lead oxide formed as a combustion product.
Lewisite	243	National Disposal Site	3×10^{-6}	1.5×10^{-5}	VII	Concentrated: Incineration - products of combustion are carbon dioxide, water, HCl, and arsenic trioxide. The arsenic trioxide is removed by alkaline scrubbing, converted to insoluble magnesium salt and placed in controlled storage. Dilute: Chlorination (conversion products are arsenic trioxide and dichloroethene which need further treatment); Hydrolysis
Lithium Aluminum Hydride	244	Industrial Disposal	0.00025	0.00125	XII	The waste material is mixed with dry sand before adding to water. The hydrogen gas liberated is burned off with a pilot flame. The remaining residue is a hydroxide and should be neutralized by an acid before being disposed of.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Magnesium Arsenite	245	National Disposal Site	.005 (as As)	.05 (as As)	VI	Long term storage in weatherproof and sift proof storage bins or silos; landfill in a California Class 1 site.
Magnesium Chlorate	246	Industrial Disposal	0.01	125 (as Mg)	XII	Dissolve the material in water and add to a large volume of concentrated reducing agent solution, then acidify the mixture with H_2SO_4. When reduction is complete, soda ash is added to make the solution alkaline. The alkaline liquid is decanted from any sludge produced, neutralized, and diluted before discharge to a sewer or stream. The sludge is landfilled.
Magnesium Oxide	247	Municipal Type Disposal	0.10	125	XII	Landfill in a California Class 2 type facility.
Maleic Anhydride	249	Municipal Type Disposal	0.01	0.05	XI	Concentrated: Controlled incineration - care must be taken that complete oxidation to nontoxic products occurs. Dilute: Neutralization by NaOH addition followed by biological oxidation.
Manganese	499	Municipal Type Disposal	0.05	0.05	XIII	Landfill.
Manganese Arsenate	500	National Disposal Site	.005 (as As)	.05 (as As)	VI	Long term storage in large, weatherproof, and siftproof storage bins or silos; landfill in a California Class 1 site.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Manganese Chloride	501	Industrial Disposal	0.05 as Mn	0.05 as Mn	XIII	Chemical conversion to the oxide followed by landfill or conversion to the sulfate for use in fertilizer.
Manganese Methylcyclopentadienyltricarbonyl	502	Industrial Disposal	0.05 (as Mn)	0.05 (as Mn)	XI	Oil Soluble Stream: Incineration with scrubbing to bring the air emissions to an acceptable level. The effluent from the scrubber can be combined with the water soluble waste stream. Dilute Waste: Precipitation of the manganese by addition of lime in a settling pond prior to discharging into the local river.
Manganese Sulfate	252	Industrial Disposal	0.05 as Mn	0.05 as Mn	XIII	Chemical conversion to the oxide followed by landfill or purification of the sulfate for use as fertilizer.
Mannitol Hexanitrate	532	National Disposal Site	.02	0.1	VII	Incineration followed by an afterburner to abate NOx, and cyclones and scrubbing towers for removal of metallic dusts and fumes.
Mercuric Chloride	253	National Disposal Site	.0005 (as Hg)	.005 (as Hg)	VI	Concentrated: Incineration followed by recovery/removal of mercury from the gas stream. Dilute aqueous: Ion exchange; reduction with sodium borohydride with removal of the elemental mercury - the effluent is sent to polishing filters (Ventron Process). Dilute gaseous: Adsorption with molecular sieves; sodium hypochlorite scrubbing.
Mercuric Cyanide	254	National Disposal Site	.0005 (as Hg)	.005 (as Hg)	VI	Aqueous wastes: After alkaline chlorination to destroy the cyanide ion, sodium borohydride is used to reduce mercury ions to the metal. The mercury is collected by filtering and purified by vacuum distillation.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Mercuric Diammonium Chloride	503	National Disposal Site	.0005 (as Hg)	.005 (as Hg)	VI	Concentrated: Incineration followed by recovery/removal of mercury from the gas stream. Dilute aqueous: Ion exchange; reduction with sodium borohydride with removal of the elemental mercury - the effluent is sent to polishing filters (Ventron Process). Dilute gaseous: Adsorption with molecular sieves; sodium hypochlorite scrubbing.
Mercuric Nitrate	255	National Disposal Site	.0005 (as Hg)	.005 (as Hg)	VI	Concentrated: Incineration followed by recovery/removal of mercury from the gas stream. Dilute aqueous: Ion exchange; reduction with sodium barohydride with removal of the elemental mercury - the effluent is sent to polishing filters (Ventron Process). Dilute gaseous: Adsorption with molecular sieves; sodium hypochlorite scrubbing.
Mercuric Sulfate	256	National Disposal Site	.0005 (as Hg)	.005 (as Hg)	VI	Concentrated: Incineration followed by recovery/removal of mercury from the gas stream. Dilute aqueous: Ion exchange; reduction with sodium barohydride with removal of the elemental mercury - the effluent is sent to polishing filters (Ventron Process). Dilute gaseous: Adsorption with molecular sieves; sodium hypochlorite scrubbing.
Mercury	257	National Disposal Site	.0005 (as Hg)	.005 (as Hg)	VI	Concentrated: Incineration followed by recovery/removal of mercury from the gas stream. Dilute aqueous: Ion exchange; reduction with sodium barohydride with removal of the elemental mercury - the effluent is sent to polishing filters (Ventron Process). Dilute gaseous: Adsorption with molecular sieves; sodium hypochlorite scrubbing.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Mercury Compounds (Organic)	258	National Disposal Site	Alkyl-mercury compounds .0001 Other organic mercury compounds .0005	Alkyl-mercury compounds .0005 Other organic mercury compounds .0025	VI	Concentrated: Incineration followed by recovery/removal of mercury from the gas stream. Dilute: Organic mercury compounds are converted to inorganic mercury compounds usinn chlorine - the inorganic mercury compounds are reduced with sodium borohydride to elemental mercury. The elemental mercury is removed and the effluent is sent to polishing filters.
Mercuric Fulminate	533	National Disposal Site	.0005 (as Hg)	.005 (as Hg)	VII	Incineration (Army Materiel Command Deactivation Furnace) followed by caustic or soda ash gas scrubbing. The mercury is removed from the scrubbing solution.
Mesityl Oxide	259	Municipal Type Disposal	1.0	5.0	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Metallic Mixture of Powdered Magnesium and Aluminum	260	Industrial Disposal	0.1	0.25 as Mg	XII	Landfill in California Class 2 type sites.
Methanol	261, 264	Municipal Type Disposal	2.6	13	X	Concentrated: Controlled incineration Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Methyl Acetate	262	Municipal Type Disposal	6.1	30.5	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Methyl Acrylate	263	Municipal Type Disposal	0.35	1.8	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Methylamine	265	Munciipal Type Disposal	0.12	0.60	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Methyl Amyl Alcohol	266	Municipal Type Disposal	1.0	5	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
n-Methylaniline	280	Industrial Disposal	0.09	0.45	X	Concentrated: Controlled incineration whereby oxides of nitrogen are removed from the effluent gas by scrubber, catalytic or thermal device. Dilute: Oxidation by activated sludge; adsorption on activated carbon.
Methyl Bromide	267	Industrial Disposal	0.6	1.80	XI	Concentrated: Controlled incineration with adequate scrubbing and ash disposal facilities. Dilute: Steam stripping - the waste gases from stripping must be burned in incinerators equipped with adequate scrubbing equipment. Removal from air: Refrigerated condensation.
Methyl Chloride	268	Industrial Disposal	2.1	10.5	XI	Concentrated: Controlled incineration with adequate scrubbing and ash disposal facilities. Dilute: Steam stripping--the waste gases from stripping must be burned in incinerators equipped with adequate scrubbing equipment. Removal from air: Refrigerated condensation.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Methyl Chloroformate	269	Industrial Disposal	0.03	0.15	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Methyl Formate	270	Municipal Type Disposal	2.5	12.5	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Methyl Isobutyl Ketone	271	Municipal Type Disposal	4.1	20.5	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal treatment plants.
Methyl Mercaptan	272	Industrial Disposal	0.01	0.075	X	Concentrated: Incineration followed by effective scrubbing of the effluent gas. Dilute waste: Incineration (2000 F) followed by scrubbing with a caustic solution.
Methyl Methacrylate, Monomer	273	Municipal Type Disposal	4.1	20.5	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Methyl Parathion	274	National Disposal Site	.002	.001	V	Concentrated: Incineration (1500 F, 0.5 seconds minimum for primary combustion; 2200 F, 1.0 second for secondary combustion) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated-carbon beds; primary waste treatment followed by an activated sludge process.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Mill Tailings, Copper	275	Industrial Disposal	Not Available	Not Available	XIII	Earth dams are constructed by retaining the tailings to the planned height. After the dams are completed, the trailings are deposited behind the dams in essentially the same manner as ould be used to fill a water reservoir. Such dams are usually designed and constructed to water retention standards.
Mill Tailings, Lead and Zinc	276	Industrial Disposal	Not Available	Not Available	XIII	Earth dams are constructed for retaining the tailings to the planned height. After the dams are completed, the tailings are deposited behind the dams in essentially the same manner as would be used to fill a water reservoir. Such dams are usually designed and constructed to water retention standards.
Mixed Acids	277	Industrial Disposal	0.01 to 0.05	0.05 to 0.25	XII	The addition of soda ash--slaked lime to form insoluble precipitates and a neutral solution. The precipitate is filtered out and the solution is discharged after dilution.
Morpholine	281	Municipal Type Disposal	0.06	0.30	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Cnemically and biologically degraded via municipal waste treatment system.
Mud, Domestic Bauxite	282	Industrial Disposal	Not Available	Not Available	XIII	Earth dams are constructed for retaining the tailings to the planned height. After the dams are completed, the tailings are deposited behind the dams in essentially the same manner as would be used to fill a water reservoir. Such dams are usually designed and constructed to water retention standards.
Mud, Foreign Bauxite	283	Industrial Disposal	Not Available	Not Available	XIII	Earth dams are constructed for retaining the tailings to the planned height. After the dams are completed, the tailings are deposited behind the dams in essentially the same manner as would be used to fill a water reservoir. Such dams are usually designed and constructed to water retention standards.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Naphtha (crude)	284	Municipal Type Disposal	4	20	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture).
Naphthalene	285	Municipal Type Disposal	0.5	2.5	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture).
B-Naphthylamine	286	Industrial Disposal	0	0	X	Concentrated: Controlled incineration whereby oxides of nitrogen are removed from the effluent gas by scrubber, catalytic or thermal device. Dilute: Oxidation by activated sludge; adsorption on activated carbon.
Nickel Ammonium Sulfate	290	Industrial Disposal	0.01 (as Ni)	0.05 (as Ni)	XIII	Concentrate and recycle through the use of reverse osmosis or multiple effect evaporators. Conversion to the insoluble carbonate followed by separation and acidification yielding formation of concentrated nickel chloride or sulfate.
Nickel Antimonide	291	Industrial Disposal	0.005 (as Sb)	0.05 (as Sb)	XIII	Encapsulation followed by landfill in California Class 1 type landfills.
Nickel Arsenide	292	Industrial Disposal	0.005 (as As)	0.05 (as As)	XIII	Encapsulation followed by landfill in California Class 1 type landfills.
Nickel Carbonyl	293	National Disposal Site	.00007	.00035	VIII	Thermal decompsoition and wet scrubbing for disposal of small quantities.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Nickel Chloride	294	Industrial Disposal	0.01 (as Ni)	0.05 (as Ni)	XIII	Concentrate and recycle through tne use of reverse osmosis or multiple effect evaporators. Conversion to the insoluble carbonate followed by separation and acidification yielding formation of concentrated nickel chloride or sulfate.
Nickel Cyanide	295	National Disposal Site	.01 (as Ni)	.01 (as Cn)	V	Oxidation by the hypochlorite ion (chlorination under alkaline conditions) for both dilute and concentrated wastes. Concentrated wastes should be diluted before chlorination.
Nickel Nitrate	296	Industrial Disposal	0.01 (as Ni)	0.05 (as Ni)	XIII	Concentrate and recycle through the use of reverse osmosis or multiple effect evaporators. Conversion to the insoluble carbonate followed by separation and acidification yielding formation of concentrated nickel chloride or sulfate.
Nickel Selenide	297	Industrial Disposal	0.002 (as Se)	0.01 (as Se)	XIII	Encapsulation followed by landfill in California Class 1 type landfills.
Nickel Sulfate	298	Industrial Disposal	0.01 (as Ni)	0.05 (as Ni)	XIII	Concentrate and recycle through the use of reverse osmosis or multiple effect evaporators. Conversion to the insoluble carbonate followed by separation and acidification yielding formation of concentrated nickel chloride or sulfate.
Nitric Acid	299	Industrial Disposal	0.01	0.25	XII	Soda ash--slaked lime is added to form the neutral solution of nitrate of sodium and calcium. This solution can be discharged after dilution with water.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Nitroaniline (Meta, para-nitroniline)	300	Industrial Disposal	0.06	0.03	XI	Concentrated: Incineration (1800 F, 2.0 seconds minimum) followed by scrubbing for removal of NOx. Dilute: It is recommended that dilute streams be concentrated, then incinerated.
Nitrobenzene	301	Industrial Disposal	0.05	0.25	XI	Concentrated: Incineration (1800 F, 2.0 seconds minimum) with scrubbing for NOx abatement. Dilute: Primary waste water treatment followed by treatment with lime to adjust the pH from 2.5 to 7. The effluent is mixed with municipal sewage and allowed to equilibrate, followed by lagooning with mechanical aeration. Secondary treatment utilizing acclimated activated sludge is recommended.
Nitrocellulose	534	National Disposal Site	Not Available	Not Available	VII	Controlled incineration--incinerator is equipped with scrubber for NOx abatement. Obsolete munitions should be disposed of using the Chemical Agent Munition Disposal System.
Nitrochlorobenzene (Meta, or para)	302	Industrial Disposal	0.01	0.05	XI	Concentrated: Incineration (1500 F, 0.5 seconds for primary combustion; 2200 F, 1.0 second for secondary combustion). The formation of elemental chlorine can be prevented through injection of steam or methane into the combustion process. NOx may be abated through the use of thermal or catalytic devices. Dilute: Landfill in a California Class 1 type site.
Nitroethane	303	Industrial Disposal	3.1	15.5	XI	Incineration--large quantities of material may require NOx removal by catalytic or scrubbing processes.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/1)		
Nitrogen Mustard	306	National Disposal Site	3×10^{-6}	1.5×10^{-5}	VII	Incineration--combustion products are carbon dioxide, water, HCl and nitrogen oxides. The nitrogen oxides require scrubbing or reduction to nitrogen and oxygen before the combustion gases are released to the atmosphere. Chemical reaction (after acidulation) with calcium hypochlorite to yield aldehydes, chloramines, and chlorates.
Nitroglycerin	307	National Disposal Site	*.002 ppm *Note these units are ppm not mg/M^3	0.1	VII	Incineration--exit gases should be scrubbed in a packed tower with a solution of caustic soda or soda ash. (U.S. Army Materiel Command Deactivation Furnace)
Nitromethane	308	Industrial Disposal	2.5	12.5	XI	Incineration--large quantities of material may require NOx removal by catalytic or scrubbing processes.
Nitroparaffins	309	Industrial Disposal	0.002	0.010	XI	Concentrated: Controlled incineration--care must be taken to maintain complete combustion at all times. Incineration of large quantities may require scrubbers to control the emission of NOx. Dilute: Biodegradation with acclimated activated sludge.
4-Nitrophenol	310	Industrial Disposal	0.002	0.01	XI	Concentrated: Controlled incineration--care must be taken to maintain complete combustion at all times. Incineration of large quantitites may require scrubbers to control the emission of NOx. Dilute: Biodegradation with acclimated activated sludge.
1&2-Nitropropane	311	Industrial Disposal	1-Nitropropane 0.90 2-Nitropropane 0.90	1-Nitropropane 4.5 1-Nitropropane 4.5	XI	Incineration--large quantities of material may require NOx removal by catalytic or scrubbing processes.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
4-Nitrotoluene	312	Industrial Disposal	0.30	1.50	XI	Concentrated: Controlled incineration--care must be taken to maintain complete combustion at all times. Incineration of large quantities may require scrubbers to control the emission of NOx. Dilute: Biodegradation with acclimated activated sludge.
Nitrous Oxide	313	Industrial Disposal	0.09	0.45	XII	Nitrous oxide can be safely discharged directly into the atmosphere with an excess of air, because it would not lead to the formation of photochemical smog or cause a harmful, toxic effect.
Nonyl Phenol	314	Municipal Type Disposal	0.19	0.001	X	Concentrated: Controlled incineration. Dilute: Biological treatment with activated sludges via municipal waste treatment plants.
Octyl Alcohol (Ethyl Hexanol)	191	Municipal Type Disposal	1.0	5.0	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Oleic Acid	316	Municipal Type Disposal	.25	1.25	X	Concentrated: Controlled incineration. Dilute: Chemical or biological degradation via municipal waste treatment systems.
Oxalic Acid	317	Industrial Disposal	0.01	0.05	XI	Chemical reaction with limestone or calcium oxide forming calcium oxalate. This may then be incinerated utilizing particulate collection equipment to collect calcium oxide for recycling. Biological treatment with activated sludge is also adequate.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Paraformaldehyde	320	Municipal Type Disposal	0.06	0.15	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Parathion	321	National Disposal Site (NDS)	.001	.005	V	Concentrated: Incineration (1,500 F, 0.5 seconds minimum for primary combustion; 2,200 F, 1.0 second for secondary combustion) with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated-carbon beds; primary waste treatment followed by an activated sludge process.
Pentaborane	505	National Disposal Site	.0001	.0005	VII	Refer to Boron Hydrides
Pentachlorophenol	322	National Disposal Site	.005	0.25	VIII	Concentrated: Incineration (600-900 C) coupled with adequate scrubbing and ash disposal facilities. Dilute: Adsorption with activated-carbon beds; Ion exchange.
Pentaerythritol Tetranitrate (PETN)	319	National Disposal Site	.02	0.1	VII	The PETN is dissolved in acetone and incinerated. The incinerator should be equipped with an after burner and a caustic soda solution scrubber. Surplus munitions should be disposed of by the U.S. Army Materiel Command's Deactivation Furnace.
n-Pentane	323	Municipal Type Disposal	15	75	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture).

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Perchloretnylene	325	Industrial Disposal	6.70	33.5	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Perchloric Acid (to 72 percent strength)	324	National Disposal Site	.01	.05	VIII	Hot reduction of the perchloric ion to chloride with heated ferrous sulfate and dilute sulfuric acid. The reduction products must be tested to determine that complete reduction of the perchlorate ion has occurred.
Perchloryl Fluoride	326	National Disposal Site	.025	.61 to 1.7	VII	Reaction with a charcoal bed. The products are carbon tetrafluoride, carbon dioxide, and chlorine. The carbon tetrafluoride is vented and the chlorine and carbon dioxide are removed by a caustic scrubber.
Phenylhydrazine Hydrochloric	328	Industrial Disposal	0.22	1.10	X	Concentrated: Controlled incineration whereby oxides of nitrogen are removed from the effluent gas by scrubber, catalytic or thermal device. Dilute: Oxidation by activated sludge; adsorption on activated carbon.
Phosgene (Gas)	101, 329	Industrial Disposal	0.004	0.02	XI	Reaction of dilute phosgene-airstreams with steam in a carbon-packed, jacketed glass column ("proof of concept" experiments should be run for safe system design).
Phosphorous (White or Yellow)	332	Industrial Disposal	0.001	0.005	XIII	Dilute waste: Controlled incineration followed by alkaline scrubbing and particulate removal equipment. Concentrated waste: Purify for recycling purposes using distillation followed by condensation under water. May be directly charged to an electric furnace for phosphorus production.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Phosphorous Oxychloride	333	Industrial Disposal	0.07 (as HCl)	0.35	XIII	Decompose with water forming phosphoric and hydrochloric acids. Neutralize acids and dilute if necessary for discharge into the sewer system.
Phosphorous Pentachloride	334	Industrial Disposal	0.01	0.05	XIII	Decompose with water forming phosphoric and hydrochloric acids. Neutralize acids and dilute if necessary for discharge into the sewer system.
Phosphorous Pentasulfide	335	Industrial Disposal	0.01	0.05	XIII	Decompose with water forming phosphoric acid, sulfuric acid and hydrogen sulfide. Provisions must be made for scrubbing hydrogen sulfide emissions. The acids may then be neutralized and diluted if necessary, and discharged into the sewer system.
Phosphorous Trichloride	336	Industrial Disposal	0.03	0.15	XIII	Decompose with water forming phosphoric and hydrochloric acids. Neutralize acids and dilute if necessary for discharge into the sewer system.
Phthalic Anhydride	337	Municipal Type Disposal	0.12	0.60	X	Concentrated: Controlled incineration. Dilute: Reaction with a basic solution to produce a soluble phthalate salt followed by chemical or biological degradation via municipal waste treatment systems.
Picric Acid	338	National Disposal Site	0.001	0.005	VII	Controlled incineration in a rotary kiln incinerator equipped with particulate abatement and wet scrubber devices. Obsolete munitions containing picric acid should be disposed of using the Chemical Agent Munition Disposal System.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/1)		
Polychlorinated Biphenyls	507	Industrial Disposal	Lower Chlorinated Aroclors 0.01 Higher Chlorinated Aroclors 0.005	Lower Chlorinated Aroclors 0.05 Higher Chlorinated Aroclors 0.025	XI	Concentrated: Incineration (3000 F) with scrubbing to remove any chlorine containing products. Dilute waste: Incineration after concentrating the stream.
Polypropylene Glycol Methyl Ether	339	Industrial Disposal	2.0	10	XI	Concentrated waste containing no peroxides: Discharge liquid at a controlled rate near a pilot flame. Concentrated waste containing peroxides: Perforation of a container of the waste from a safe distance followed by open burning. Dilute Waste: Incineration (1500 F minimum).
Polyvinyl Chloride	340	Industrial Disposal	Not Available	Not Available	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Polyvinyl Nitrate (PVN)	535	Industrial Disposal	Not Available	Not Available	XI	Controlled incineration-- incinerator is equipped with scrubber for NOx abatement.
Potassium Arsenite	341	National Disposal Site	.005 (as As)	.05 (as As)	VI	Long term storage in large weatherproof and siftproof storage bins or silos; Landfill in a California Class 1 site.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Potassium Bifluoride	545	Industrial Disposal	0.025 (as F)	0.6-1.7 (as F)	XII	Aqueous Waste: Reaction with an excess of lime, followed by lagooning, and either recovery or landfill disposal of the separated calcium fluoride. The supernatant liquid from this process is diluted and discharged to the sewer.
Potassium Binoxalate	342	Industrial Disposal	0.02	0.10	XII	Ignition--to convert it to a carbonate. Since carbonates are non-toxic, tne material may be sent to a landfill or simply sewered.
Potassium Chromate	343	National Disposal Site	.001 (as CrO_3)	.05 (as Cr)	VI	Concentrated: Reduction/Precipitation with hydroxide ion. Dilute: Reduction/Precipitation; Ion Exchange.
Potassium Cyanide (Solid)	344	National Disposal Site	.05 (as Cn)	.01 (as Cn)	V	Oxidation by the hypochlorite ion (chlorination under alkaline conditions) for both dilute and concentrated wastes. Concentrated wastes should be diluted before chlorination.
Potassium Dichromate	345	National Disposal Site	.001 (as CrO_3)	.05 (as Cr)	VI	Concentrated: Reduction/Precipitation with hydroxide ion. Dilute: Reduction/Precipitation; Ion Exchange.
Potassium Dinitrobenzfuroxan (KDNBF)	536	National Disposal Site	Not Available	Not Available	VII	Obsolete munitions should be disposed of using the Chemical Agent Munition Disposal System under development by the U.S. Army Materiel Command.
Potassium Fluoride	346	Industrial Disposal	0.025 (as F)	0.6-1.7 (as F)	XII	Aqueous Waste: Reaction with an excess of lime, followed by lagooning, and either recovery or landfill disposal of the separated calcium fluoride. The supernatant liquid from this process is diluted and discharged to the sewer.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M³)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Potassium Hydroxide	347	Industrial Disposal	0.02	0.10	XII	Dissolve in water followed by neutralization with an acid and sewering.
Potassium Oxalate	348	Industrial Disposal	0.01 (as oxalic acid)	0.05	XII	Ignition-to convert it to a carbonate. Since carbonates are nontoxic, the material may be sent to a landfill or simply sewered.
Potassium Permanganate	349	Industrial Disposal	0.05 (as Mn)	0.05 (as Mn)	XIII	Chemical reduction in a basic media resulting in insoluble magnaese dioxide formation. This material may be collected and placed in landfills.
Potassium Peroxide	350	Industrial Disposal	0.014 (as H_2O_2)	0.1 (as KOH)	XIII	Neutralize liquid waste if necessary and dilute for discharge into the sewer system.
Potassium Phosphate	351	Municipal Type Disposal	0.01	0.05 (as H_3PO_4)	XII	The material is diluted to the recommended provisional limit in water. The pH is adjusted to between 6.5 and 9.1 and then the material can be discharged into sewers or natural streams.
Potassium Sulfate	352	Municipal Type Disposal	0.01 (as H_2SO_4)	250 (as SO_4)	XII	Potassium sulfate is relatively harmless and can be diluted to a concentration below 250 mg/liter and released to sewers and waterways.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Potassium Sulfide	353	Municipal Type Disposal	0.15 (as H_2S)	0.75 (as H_2S)	XII	Precipitation with ferric chloride solution. The insoluble FeS formed is removed by filtration. The remaining potassium chloride solution can be diluted to a concentration below 250 mg/l and discharged to sewers and waterways.
Primers and Detonators	520	National Disposal Site	Not Available	Not Available	VII	The Chemical Agent Munition Disposal System which includes a Deactivation Furnance should be used (under development by the U.S. Army Materiel Command).
Propane	354	Municipal Type Disposal	50	50	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixtures)
Propionaldehyde	355	Municipal Type Disposal	0.1	0.5	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Propionic Acid	356	Municipal Type Disposal	0.25	1.25	X	Concentrated: Incineration. Dilute: Biodegradation with unacclimated activated sludges in municipal treatment plants.
n-Propyl Acetate	357	Municipal Type Disposal	8.4	42.0	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
n-Propyl Alcohol	358	Municipal Type Disposal	5.0	25	X	Concentrated: Controlled incineration. Dilute. Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Propylamine (mono-n-)	359	Municipal Type Disposal	0.12	0.60	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Propylene	360	Municipal Type Disposal	22	110	X	Concentrated: Incineration. Dilute: Discharge of dilute acqueous solutions into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture).
Propylene Glycol	361	Municipal Type Disposal	2.0	10	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Propylene Oxide	362	Industrial Disposal	2.4	12	XI	Concentrated waste containing no peroxides: Discharge liquid at a controlled rate near a pilot flame. Concentrated waste containing peroxides: Perforation of a container of the waste from a safe distance followed by open burning. Dilute waste: Incineration (1500 F minimum).
Pyridine	364	Industrial Disposal	0.15	0.75	X	Concentrated: Controlled incineration whereby oxides of nitrogen are removed from the effluent gas by scrubber, catalytic or thermal devices. Dilute: Oxidation by activated sludge; adsorption on activated carbon.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Quinone	365	Municipal Type Disposal	0.001	0.02	XI	Concentrated waste: Controlled incineration (1800 F, 2.0 seconds minimum). Dilute waste: Biological treatment utilizing acclimated activated sludge.
Salicylic Acid	366	Municipal Type Disposal	0.25	1.25	X	Concentrated: Incineration. Dilute: Biodegradation with unacclimated activated sludges in municipal treatment plants.
Selenium, Powdered	367	Industrial Type Disposal	0.002	0.01	XIII	Vapors and particulate may be acid scrubbed with an HBr solution with subsequent recovery of selenium utilizing distillation. Landfilled in California Class 1 type site.
Silica	368	Industrial Disposal	0.1	0.5	XII	Landfill in California Class 2 type sites.
Silicon Tetrachloride	369	Industrial Disposal	0.01	0.50	XII	Addition of soda ash-slaked lime solution to form the corresponding sodium and calcium salt solution. This solution can be safely discharged after dilution.
Silver Acetylide	537	National Disposal Site (NDS)	Not Available	Not Available	VII	Detonation (on an interim basis until a fully satisfactory technique is developed).

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	 Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Silver Azide	538	National Disposal Site	.0001	.05	VII	Oxidation with nitrous acid. Any NOx fumes evolved should be removed by scrubbing with an alkaline solution. The silver present should be recovered by electrolysis. Obsolete munitions should be disposed of by the Chemical Agent Munition Disposal System.
Silver Cyanides	370	National Disposal Site	.0001 (as Ag)	.01 (as Cn)	V	Oxidation by the hypochlorite ion (chlorination under alkaline conditions) for both dilute and concentrated wastes. Concentrated wastes should be diluted before chlorination.
Silver Styphnate	539	National Disposal Site (NDS)	.0001 (as Ag)	.05 (as Ag)	VII	Controlled combustion employing a rotary kiln incinerator equipped with appropriate scrubbing devices. The explosive is fed to the incinerator as a slurry in water. The scrubber effluent would require treatment for recovery of particulate metal compounds formed as combustion products.
Silver Tetrazene	540	National Disposal Site	.0001 (as Ag)	.05 (as Ag)	VII	Controlled combustion employing a rotary kiln incinerator equipped with appropriate scrubbing devices. The explosive is fed to the incinerator as a slurry in water. The scrubber effluent would require treatment for recovery of particulate metal compounds formed as combustion products.
Slag I (SIC 3331) Copper Smelting	371	Municipal Type Disposal	Not Available	Not Available	XIII	The slag is deposited in a landfill.
Slag II (SIC 3332) Lead Smelting	372	Municipal Type Disposal	Not Available	Not Available	XIII	The slag is deposited in a landfill.
Smokeless Gunpowder	541	National Disposal Site	Not Available	Not Available	VII	Controlled incineration--incinerator is equipped with scrubber for NOx abatement. Obsolete munitions should be disposed of using the Chemical Agent Munition Disposal System.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Sodium Alloy	374	Industrial Disposal	0.02 as NaOH	0.1 as NaOH	XIII	Controlled incineration with subsequent effluent scrubbing.
Sodium Acid Sulfite	380	Municipal Type Disposal	0.02	0.10	XIII	Dilution with large volumes of water followed by reaction with soda ash, calcium hypochlorite and HCl followed by discharge into the sewer system.
Sodium Amide	375	Industrial Disposal	0.02	0.10	XII	Hydrolyzes rapidly to form sodium hydroxide and ammonia, both of which can be neutralized by hydrochloric or sulfuric acid. The neutral solution can be safely discharged if the salt content is below the limits set to maintain water quality.
Sodium Arsenate	376	National Disposal Site (NDS)	.05 (as As)	.05 (as As)	VI	Long term storage in large, weatherproof, and siftproof storage bins or silos; Landfill in a California Class 1 site.
Sodium Arsenite	377	National Disposal Site	.005 (as As)	.05 (as As)	VI	Long term storage in large weatherproof and siftproof storage bins or silos; Landfill in a California Class 1 site.
Sodium Azide	378	Industrial Disposal	0.02	0.1	XIII	Reaction with sulfuric acid solution and sodium nitrate in a hard rubber vessel. Nitrogen dioxide is generated by this reaction and the gas is run through a scrubber before it is released to the atmosphere. Controlled incineration is also acceptable (after mixing with other combustible wates) with adequate scrubbing and ash disposal facilities.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Sodium Bifluoride	546	Industrial Disposal	0.025 (as F)	0.6-1.7 (as F)	XII	Aqueous Waste: Reaction with an excess of lime, followed by lagooning, and either recovery or landfill disposal of the separated calcium fluoride. The supernatant liquid from this process is diluted and discharged to the sewer.
Sodium Cacodylate	382	National Disposal Site	.005	.05	VI	Long-term storage in concrete vaults or weatherproof bins; Landfill in a California "Class 1" site.
Sodium Carbonate	383	Municipal Type Disposal	0.02	0.10	XII	The material is diluted to the recommended provisional limit in water. The pH is adjusted to between 6.5 and 9.1 and then the material can be discharged into sewers or natural streams.
Sodium Carbonate Peroxide	384	Industrial Disposal	0.02	0.10	XII	Dissolve the material in water and add to a large volume of concentrated reducing agent solution, then acidify the mixture with H_2SO_4. When reduction is complete, soda ash is added to make the solution alkaline. The alkaline liquid is decanted from any sludge produced, neutralized, and diluted before discharge to a sewer or stream. The sludge is landfilled.
Sodium Chlorate	385	Industrial Disposal	0.02	0.10	XIII	Chemical reduction with iron filings or waste pickle liquor followed by reaction with lime, soda ash or sodium hydroxide followed by lagooning.
Sodium Chromate	386	National Disposal Site	.001 (as CrO_3)	.05 (as Cr)	VI	Concentrated: Reduction/Precipitation with hydroxide ion. Dilute: Reduction/Precipitation; Ion Exchange.
Sodium Cyanide	387	National Disposal Site	.05 (as Cn)	.01 (As Cn)	V	Oxidation by the hypochlorite ion (chlorination under alkaline conditions) for both dilute and concentrated wastes. Concentrated wastes should be diluted before chlorination.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M3)	Water and Soil (mg/l)		
Sodium Dichromate	379	National Disposal Site	.001 (as CrO_3)	.05 (as Cr)	VI	Concentrated: Reduction/Precipitation with hydroxide ion. Dilute: Reduction/Precipitation; Ion Exchange
Sodium Fluoride	389	Industrial Disposal	0.025 (as F)	0.6-1.7 (as F)	XII	Aqueous Waste: Reaction with an excess of lime, followed by lagooning, and either recovery or landfill disposal of the separated calcium fluoride. The supernatant liquid from this process is diluted and discharged to the sewer.
Sodium Formate	390	Municipal Type Disposal	.09	0.45	V	Concentrated: Conversion to formic acid followed by controlled incineration. Dilute: Chemical or biological degradation via municipal waste treatment systems.
Sodium Hydride (Crystals)	391	Industrial Disposal	0.02	0.10	XII	The waste material is mixed with dry sand before adding to water. The hydrogen gas liberated is burned off with a pilot flame. The remaining residue is a hydroxide and should be neutralized by an acid before being disposed of.
Sodium Hydrosulfite	392	Industrial Disposal	0.02	0.10	XII	Oxidation to yield sodium sulfate with the liberation of sulfur dioxide. The exhaust gas is scrubbed to remove the SO_2 gas. The soluble sodium sulfate is converted to the insoluble calcium sulfate which is removed by filtration and sent to landfill. The filtrate is diluted and discharged.
Sodium Iodide	395	Industrial Disposal	0.02	0.10	XIII	Chemical reaction utilizing either the "Silver Iodide Process" or the "Blow Out Process".

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Sodium Nitrate (Solid)	396	Municipal Type Disposal	0.05	45	XII	The material is dilute to the recommended provisional limit in water. The pH is adjusted to between 6.5 and 9.1 and then the material can be discharged into sewers or natural streams.
Sodium Nitrite (Solid)	397	Municipal Type Disposal	0.02	0.10	XIII	Dilution with large volumes of water followed by reaction with soda ash, calcium hypochlorite and HCl followed by discharge into the sewer system.
Sodium Orthophosphates	401	Municipal Type Disposal	0.01	0.05 (as H_3PO_4)	XII	The material is diluted to the recommended provisional limit in water. The pH is adjusted to between 6.5 and 9.1 and then the material can be discharged into sewers or natural streams.
Sodium Oxalate	398	Municipal Type Disposal	.01	.05	X	Concentrated: Conversion to oxalic acid followed by controlled incineration. Dilute: Chemical or biological degradation via municipal waste treatment systems.
Sodium Oxide	508	Industrial Disposal	0.02 (as NaOH)	0.1 (as NaOH)	XIII	Chemical neutralization followed by solids separation with deposit of solids into California Class 1 landfill sites. The supernatant is diluted and discharged into sewers and streams.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Sodium Perchlorate	399	Industrial Disposal	0.02	0.10	XII	Dissolve the material in water and add to a large volume of concentrated reducing agent solution, then acidify the mixture with H_2SO_4. When reduction is complete, soda ash is added to make the solution alkaline. The alkaline liquid is decanted from any sludge produced, neutralized, and diluted before discharge to a sewer or stream. The sludge is landfilled.
Sodium Peroxide	400	Industrial Disposal	0.014 as H_2O_2	0.1 as NaOH	XIII	Neutralize liquid waste if necessary and dilute for discharge into the sewer system.
Sodium Potassium Alloy	402	Industrial Disposal	0.02 as NaOH	0.1 as NaOH	XIII	Controlled incineration with subsequent effluent scrubbing.
Sodium Silicates	403	Municipal Type Disposal	0.02	0.10	XIII	Acidification with HCl followed by neutralization, dilution with water and release into the sewer system.
Sodium Sulfide	404	Industrial Disposal	0.15 (as H_2S)	0.75 (as H_2S)	XII	Converted into the insoluble ferrous sulfide by reaction with ferrous chloride solution. The ferrous sulfide precipitate may be removed by filtration and reclaimed.
Sodium Sulfite	405	Municipal Type Disposal	0.02	0.10	XIII	Dilution with large volumes of water followed by reaction with soda ash, calcium hypochlorite and HCl followed by discharge into the sewer system.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M³)	Water and Soil (mg/l)		
Sodium Thiocyanate	406	Industrial Disposal	0.02	0.10	XII	Dissolve in a large quantity of water, buffer with a slight excess of soda ash, neutralize with an acid, and sewer.
Sorbitol	407	Municipal Type Disposal	2.0	10	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated actived sludges via municipal sewage treatment plants.
Stannic Chloride	408	Industrial Disposal	0.02 (as Sn)	0.05 (as Sn)	XII	When dissolved in water and neutralized, the slightly soluble oxide is formed. Removal of the oxide is followed by sulfide precipitation to ensure the removal of the metal ion from solution. The tin oxides can be refined or landfilled.
Stannous Chloride	409	Industrial Disposal	0.02 as Sn	0.05 as Sn	XII	Chemical precipitation usually utilizing sulfuric acid to form barium sulfate which may be separated from the stream and recycled. The supernatant may then be neutralized and discharged into the sewer system.
Strontium	410	Municipal Type Disposal	Not Available	Not Available	XIII	Strontium metal is essentially non toxic and there is negligible waste generated. The waste from the occasional use of a 10 lb lot is washed down the drain whereupon it forms very dilute $Sr(OH)_2$ solution and small quantities of H_2 gas. The $Sr(OH)_2$ in the sewer line is very dilute and causes no problems. The H_2 gas is evolved slowly and is kept well below the lower flammable limit.
Styrene	412	Municipal Type Disposal	4.2	21	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; incineration (for dilute organic mixture).

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/1)	Found In Volume	Recommended Treatment
Sulfur	413	Municipal Type Disposal	0.1	500	XII	Landfill in a California Class 2 type facility.
Sulfur Dioxide	414	Industrial Disposal	0.013	0.65	XII	Removal from a gas stream: regenerative or non-regenerative alkaline absorption. These include, among others, various wet limestone scrubbing processes and scrubbing with an aqueous solution of sodium carbonate. Dilute Aqueous: Neutralization with soda ash - slaked lime solution.
Sulfur Mustard	543	National Disposal Site	3×10^{-6}	1.5×10^{-5}	VII	The sulfur mustard may be dissolved in gasoline and incinerated using the U.S. Army Materiel Command's Deactivation Furnace (Chemical Agent Munition Disposal System). The combustion products are removed by alkaline scrubbing.
Sulfur Trioxide	509	Industrial Disposal	0.01	0.05	XII	Neutralization with soda ash-slaked lime solution. Any precipitate is filtered out and the supernatant is diluted and discharged.
Sulfuric Acid	415	Industrial Disposal	0.01	0.05	XII	Precipitation with soda ash-slaked lime solution to form the insoluble calcium sulfate which is removed by filtration. The neutral supernatant liquid can be discharged after dilution.
Sulfurous Acid	416	Industrial Disposal	0.01	0.05	XII	Precipitation with soda ash--slaked lime solution to form the insoluble calcium sulfate which is removed by filtration. The neutral supernatant liquid can be discharged after dilution.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Sulfuryl Fluoride	417	Industrial Disposal	0.20	1.0	XII	Addition of soda ash-slaked lime solution to form the corresponding sodium and calcium salt solution. This solution can be safely discharged after dilution.
TNT	418	National Disposal Site	0.015	.075	VII	Incineration - The TNT is dissolved in acetone and incinerated. The incinerator should be equipped with an after burner and a caustic soda solution scrubber. Surplus munitions should be disposed of by the U.S. Army Materiel Command's Deactivation Furnace.
Taconite Tailings	419	Industrial Disposal	Not Available	Not Available	XIII	Earth dams are constructed for retaining the tailings to the planned height. After the dams are completed, the tailings are deposited behind the dams in much the same manner as would be used to fill a water reservoir. Such dams are usually designed and constructed to water retention standards.
Tantalum	510	Industrial Disposal	0.05	0.25	XII	Landfill in California Class 2 type sites.
Tear Gas (CN) (Chloroacetophenone)	422, 107	National Disposal Site	.003	Not Available	VII	The tear gas - containing waste is dissolved in an organic solvent and sprayed into an incinerator equipped with an afterburner and alkalie scrubber; Reaction with sodium sulfide in an alcohol water solution. Hydrogen sulfide is liberated and collected by an alkaline scrubber.
Tear Gas, Irritant	423	National Disposal Site	.004	.020	VII	Chemical Agent Munition Disposal System (under development by U.S. Army Materiel Command). This is an automated, scrubber equipped incineration system. Hydrolysis in 95 percent ethanol and 5 percent water followed by incineration and then by a caustic scrubber.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Tetrachloreoethane	424	Industrial Disposal	0.35	175	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Tetraethyl Lead	425	Industrial Disposal	.0010 (as Pb)	0.05 (as Pb)	XI	Controlled incineration with scrubbing for collection of lead oxides which may be recycled or landfilled. Sulfide or carbonate precipitation followed by ion exchange is also an adequate method for reducing lead levels in aqueous streams.
Tetrahydrofuran	426	Industrial Disposal	5.9	29.5	XI	Concentrated waste containing no peroxides: Discharge liquid at a controlled rate near a pilot flame. Concentrated waste containing peroxides: Perforation of a container of the waste from a safe distance followed by open burning. Dilute waste: Incineration (1500 F minimum).
Tetramethyl Lead	427	Industrial Disposal	.005 (as Pb)	0.05 (as Pb)	XI	Controlled incineration with scrubbing for collection of lead oxides which may be recylced or land filled. Sulfide or carbonate precipitation followed by ion exhcange is also an adequate method for reducing lead levels in aqueous streams.
Tetranitromethane	428	Industrial Disposal	0.08	0.4	XI	Open burning at remote burning sites. This procedure is not entirely satisfactory since it makes no provision for the control of the toxic effluents, NO_X and HCN. Suggested procedures are to employ modified closed pit burning, using blowers for air supply and passing the effluent combustion gases through wet scrubbers.
Tetrapropylene	429	Municipal Type Disposal	10	50	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solutions into the municipal sewers after preliminary treatment; Incineration, (for dilute organic mixture).

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Tetrazene	542	National Disposal Site	Not Available	Not Available	VII	Treatment with steam - tetrazene is decomposed by passing into water containing tetrazene crystals. The products of the decomposition may be sent to a sewage treatment plant. Obsolete military munitions should be disposed of using the Chemical Agent Munition Disposal System.
Thallium	430	Industrial Disposal	0.001	0.005	XIII	Concentrated: Recycle wastes utilizing extractive metallurgy. Dilute Waste: Landfill in California Class 1 type site.
Thallium Sulfate	431	Industrial Disposal	0.001 as Tl	0.005 as Tl	XIII	Concentrated: Recycle wastes utilizing extractive metallurgy. Dilute Waste: Landfill in California Class 1 type site.
Thiocyanates	432	Industrial Disposal	Variable	Variable	XII	Dissolve in a large quantity of water, buffer with a slight excess of soda ash, neutralize with an acid, and sewer.
Toluene	434	Municipal Type Disposal	3.75	18.75	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solution into the municipal sewers after primary treatment; Incineration (for dilute organic mixture).
Toluene Diisocyanate	511	Industrial Disposal	0.0014	0.007	X	Concentrated: Controlled incineration (oxides of nitrogen are removed from the effluent gas by scrubbers and/or thermal devices). Dilute: Biological treatment (highly dependent upon pH and temperature conditions); Activated carbon treatment (as a polishing step to be used in conjunction with biological treatment).

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
σ- Toluidine	435	Industrial Disposal	0.22	1.10	X	Concentrated: Controlled incineration whereby oxides of nitrogen are removed from the effluent gas by scrubber, catalytic or thermal device. Dilute: Oxidation by activated sludge; absorption on activated carbon.
Trichlorobenzene	436	Industrial Disposal	3.0	15.0	X	Incineration - preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Trichloroethane	437	Industrial Disposal	19	19	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Trichloroethylene	438	Industrial Disposal	5.35	26.76	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Trichlorofluoromethane (Freon II)	439	Industrial Disposal	56	280	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
Tricresyl Phosphate	440	Municipal Type Disposal	0.001	0.005	XI	Controlled incineration or landfill. TCP has a low solubility (20 ppm) in water so landfilling presents no excessive long-term hazard to underground water supplies.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/1)	Found In Volume	Recommended Treatment
Triethanolamine	441	Municipal Type Disposal	0.06	0.30	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Triethylamine	442	Municipal Type Disposal	1.0	5.0	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Triethylene Glycol	443	Municipal Type Disposal	2.0	10	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Triethylene Tetramine	444	Municipal Type Disposal	0.04	0.20	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Trimethylamine	445	Municipal Type Disposal	1.0	5.0	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NOx emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Tripropane (Norene)	446	Municipal Type Disposal	10	50	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solution into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture).

TABLE 7
WASTE STREAM CONSITIUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Turpentine	447	Municipal Type Disposal	5.6	28	X	Concentrated: Incineration Dilute: Discharge of dilute aqueous solution into the municipal sewers after preliminary treatment; Incineration (for dilute organic mixture).
Urea (Plus Salts)	448	Municipal Type Disposal	0.06	0.30	X	Concentrated: Controlled incineration (incinerator is equipped with a scrubber or thermal unit to reduce NO_x emissions). Dilute: Chemically and biologically degraded via municipal waste treatment system.
Vanadium Pentoxide	513	Municipal Type Disposal	0.005 for fume 0.001 for dust	0.05 as V	XII	Landfill in a California Class 2 type facility.
Vinyl Acetate	449	Municipal Type Disposal	0.3	1.5	X	Concentrated: Controlled incineration. Dilute: Biodegradation by unacclimated activated sludges via municipal sewage treatment plants.
Vinyl Chloride	450	Industrial Disposal	7.70	38.50	X	Incineration--preferably after mixing with another combustible fuel. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced.
VX (persistent nerve gas)	288	National Disposal Site	$3x10^{-6}$	Not Available	VII	Concentrated: Incineration followed by adequate gas scrubbing equipment. Dilute: Hydrolysis using caustic soda to accelerate the hydrolysis reactions.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit		Found In Volume	Recommended Treatment
			Air (mg/M^3)	Water and Soil (mg/l)		
Xylene	451	Municipal Type Disposal	4.35	4.35	X	Concentrated: Incineration. Dilute: Discharge of dilute aqueous solution into the municipal sewers after primary treatment; Incineration (for dilute organic mixture).
Xylenol (Xylol)	452	Municipal Type Disposal	0.19	0.001	X	Concentrated: Controlled incineration. Dilute: Biological treatment with activated sludges via municipal waste treatment plants.
Zinc Arsenate	453	National Disposal Site	.005 (as As)	.05 (as As)	VI	Long term storage in large, weatherproof, and siftproof storage bins or silos; Landfill in a California Class 1 site.
Zinc Arsenite	454	National Disposal Site	.005 (as As)	.05 (as As)	VI	Long term storage in large weatherproof and siftproof storage bins or silos; Landfill in a California Class 1 site.
Zinc Chlorate	455	Industrial Disposal	0.01	5.0 (as Zn)	XII	Dissolve the material in water and add to a large volume of concentrated reducing agent solution, then acidify the mixture with H_2SO_4. When reduction is complete, soda-ash is added to make the solution alkaline. The alkaline liquid is decanted from any sludge produced, neutralized, and diluted before discharge to a sewer or stream. The sludge is landfilled.
Zinc Chloride	456	Industrial Disposal	0.01	5.0 (as Zn)	XIII	Recovery of zinc utilizing reverse osmosis, multiple effect evaporation, ion exchange or precipitation as the sulfide or hydroxide.

TABLE 7 - CONTINUED
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Material No.	Treatment Category	Provisional Limit Air (mg/M^3)	Provisional Limit Water and Soil (mg/l)	Found In Volume	Recommended Treatment
Zinc Cyanide	457	National Disposal Site	.05 (as Cn)	.01 (as Cn)	V	Oxidation by the hypochlorite ion (chlorination under alkaline conditions) for both dilute and concentrated wastes. Concentrated wastes should be diluted before chlorination.
Zinc Nitrate	459	Industrial Disposal	0.05 as HNO_3	5.0 as Zn	XIII	Recovery of zinc utilizing reverse osmosis, multiple effect evaporation, ion exchange or precipitation as the sulfide or hydroxide.
Zinc Oxide	460	Municipal Type Disposal	0.05	5.0 as Zn	XIII	Landfill in a California Class 2 type facility.
Zinc Permanganate	461	Industrial Disposal	0.05 as Mn	5.0 as Z n	XIII	Recovery of zinc utilizing reverse osmosis, multiple effect evaporation, ion exchange or precipitation as the sulfide or hydroxide.
Zinc Peroxide	462	Industrial Disposal	0.14 as H_2O_2	5.0 as Zn	XIII	Recovery of zinc utilizing reverse osmosis, multiple effect evaporation, ion exchange or precipitation as the sulfide or hydroxide.
Zinc Sulfide	463	Industrial Disposal	0.15 as H_2S	5.0 as Zn	XIII	Recovery of zinc utilizing reverse osmosis, multiple effect evaporation, ion exchange or precipitation as the sulfide or hydroxide.

TABLE 7 - CONTINUED*
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Maximum Permissible Concentration (microcuries/milliliter) air	water
Americium - 241[†]	Soluble form 0.67×10^{-13}	Soluble form 1.33×10^{-6}
	Insoluble form 1.33×10^{-12}	Insoluble form 0.67×10^{-5}
Americium - 243[†]	Soluble form 0.67×10^{-13}	Soluble form 1.33×10^{-6}
	Insoluble form 1.33×10^{-12}	Insoluble form 1.0×10^{-5}
Carbon - 14[†]	Soluble form 0.33×10^{-7}	Soluble form 2.7×10^{-4}
	Submersion[§] 0.33×10^{-6}	Not applicable
Cerium - 144[†] (Praseodymium - 144)	Soluble form 1.0×10^{-10}	Soluble form 0.33×10^{-5}
	Insoluble form 0.67×10^{-10}	Insoluble form 0.33×10^{-5}
Cesium - 134[†]	Soluble form 0.33×10^{-9}	Soluble form 3.0×10^{-6}
	Insoluble form 1.33×10^{-10}	Insoluble form 1.33×10^{-5}
Cesium - 137[†] (Barium - 137m)	Soluble form 0.67×10^{-9}	Soluble form 0.67×10^{-5}
	Insoluble form 1.67×10^{-10}	Insoluble form 1.33×10^{-5}
Cobalt - 60[†]	Soluble form 0.33×10^{-8}	Soluble form 1.67×10^{-5}
	Insoluble form 1.0×10^{-10}	Insoluble form 1.0×10^{-5}
Curium - 242[†]	Soluble form 1.33×10^{-12}	Soluble form 0.67×10^{-5}
	Insoluble form 2.0×10^{-12}	Insoluble form 1.0×10^{-5}
Curium - 244[†]	Soluble form 1.0×10^{-13}	Soluble form 2.33×10^{-6}
	Insoluble form 1.0×10^{-12}	Insoluble form 1.0×10^{-5}
Iodine - 129[‡]	Soluble form $.67 \times 10^{-11}$	Soluble form 2.0×10^{-8}
	Insoluble form 0.67×10^{-9}	Insoluble form 0.67×10^{-4}
Iodine - 131[‡]	Soluble form 0.33×10^{-10}	Soluble form 1.0×10^{-7}
	Insoluble form 0.33×10^{-8}	Insoluble form 2.0×10^{-5}
Iridium - 192[†]	Soluble form 1.33×10^{-9}	Soluble form 1.33×10^{-5}
	Insoluble form 3.0×10^{-10}	Insoluble form 1.33×10^{-5}
Krypton - 85[‡]	Submersion[§] 1.0×10^{-7}	Not applicable
Niobium - 95[†]	Soluble form 0.67×10^{-8}	Soluble form 0.33×10^{-4}
	Insoluble form 1.0×10^{-9}	Insoluble form 0.33×10^{-4}

---

[*] All high-level radioactive waste stream constituents are candidates for National Disposal Site treatment. The radioactive waste stream constituent Profile Reports are presented in Volume IX.

[†] The recommended treatment sequence is recovery from the aqueous high-level waste stream, solidification at the fuel reprocessing facility, transport to the National Disposal Site for temporary storage in engineered storage facilities until ultimate disposal in salt deposits.

[‡] The recommended treatment sequence is recovery from gaseous waste streams, transport to the National Disposal Site for temporary storage in engineered storage facilities until ultimate disposal in salt deposits.

[§] The values given are for submersion in a semispherical infinite cloud of airborne material.

TABLE 7 - CONTINUED*
WASTE STREAM CONSTITUENT ANALYSIS SUMMARY

Hazardous Waste Stream Constituent	Maximum Permissible Concentration (microcuries/milliliter) air	Maximum Permissible Concentration (microcuries/milliliter) water
Plutonium - 238[†]	Soluble form 2.33×10^{-14}	Soluble form 1.67×10^{-6}
	Insoluble form 0.33×10^{-12}	Insoluble form 1.0×10^{-5}
Plutonium - 239[†]	Soluble form 2.0×10^{-14}	Soluble form 1.67×10^{-6}
	Insoluble form 0.33×10^{-12}	Insoluble form 1.0×10^{-5}
Plutonium - 240[†]	Soluble form 2.0×10^{-14}	Soluble form 1.67×10^{-6}
	Insoluble form 0.33×10^{-12}	Insoluble form 1.0×10^{-5}
Plutonium - 241[†]	Soluble form 1.0×10^{-12}	Soluble form 0.67×10^{-4}
	Insoluble form 0.33×10^{-9}	Insoluble form 0.33×10^{-3}
Promethium - 147[†]	Soluble form 0.67×10^{-9}	Soluble form 0.67×10^{-4}
	Insoluble form 1.0×10^{-9}	Insoluble form 0.67×10^{-4}
Radium - 226[†]	Soluble form 1.0×10^{-12}	Soluble form 1.0×10^{-8}
	Insoluble form 0.67×10^{-12}	Insoluble form 1.0×10^{-5}
Ruthenium - 106[†] (Rhodium - 106)	Soluble form 1.0×10^{-9}	Soluble form 0.33×10^{-5}
	Insoluble form 0.67×10^{-10}	Insoluble form 0.33×10^{-5}
Strontium - 90[†] (Yttrium - 90)	Soluble form 1.0×10^{-11}	Soluble form 1.0×10^{-7}
	Insoluble form 0.67×10^{-10}	Insoluble form 1.33×10^{-5}
H^3 - Tritium[†]	Soluble form 0.67×10^{-7}	Soluble form 1.0×10^{-3}
	Submersion[§] 1.33×10^{-5}	Not applicable
Xenon - 133[‡]	Submersion[§] 1.0×10^{-7}	Not applicable
Zirconium - 95[†]	Soluble form 1.33×10^{-9}	Soluble form 2.0×10^{-5}
	Insoluble form 0.33×10^{-9}	Insoluble form 2.0×10^{-5}

---

[*] All high-level radioactive waste stream constituents are candidates for National Disposal Site treatment. The radioactive waste stream constituent Profile Reports are presented in Volume IX.

[†] The recommended treatment sequence is recovery from the aqueous high-level waste stream, solidification at the fuel reprocessing facility, transport to the National Disposal Site for temporary storage in engineered storage facilities until ultimate disposal in salt deposits.

[‡] The recommended treatment sequence is recovery from gaseous waste streams, transport to the National Disposal Site for temporary storage in engineered storage facilities until ultimate disposal in salt deposits.

[§] The values given are for submersion in a semispherical infinite cloud of airborne material.